SUCCESS FACTORS IN THE IMPLEMENTATION AND MANAGEMENT OF AQUATIC PROTECTED AREAS

Theme 3

KEYNOTE PRESENTATION

SUCCESS FACTORS IN THE IMPLEMENTATION AND MANAGEMENT OF AQUATIC PROTECTED AREAS

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THE NATIONAL MARINE SANCTUARY PROGRAM

The National Marine Sanctuary Program (NMSP) in the United States of America, managed by the National Oceanic and Atmospheric Administration (NOAA) in the United States Department of Commerce, comprises a network of 13 aquatic protected areas (Fig. 1) that encompasses marine and freshwater resources from Washington State to the Florida Keys, and from Lake Huron to the Gulf of Mexico. The tropical Pacific Ocean has two designated Sanctuaries, one in American Samoa and another in the Hawaiian Islands. A second Hawaiian Sanctuary, encompassing the Northwest Hawaiian Islands, will be the fourteenth Sanctuary when it completes the designation process. NOAA's National Ocean Service has managed marine sanctuaries since passage of the *Marine Protection, Research and Sanctuaries Act* of 1972. Title III of that Act is now called the *National Marine Sanctuaries Act*.

The National Marine Sanctuaries provide protection to a variety of aquatic areas, including deep ocean gardens, nearshore coral reefs, whale migration corridors, deep-sea canyons, and underwater archeological sites. They range in size from less than 1 km^2 in Fagatele Bay, American Samoa, to more than 18,000 km^2 off Monterey Bay, California – one of the largest marine protected areas in the world. Together, these sanctuaries protect nearly 61,000 km^2 of coastal and open-ocean waters and habitats. While some activities are managed to protect resources, certain uses, such as recreation, commercial fishing, and shipping are allowed to the extent that they are consistent with a sanctuary's resource protection mandates. Research, education, outreach, and enforcement activities are other major components in each sanctuary's program of resource protection.

FLORIDA KEYS

The only emergent coral reefs found off the continental USA are located in the Florida Keys, from south of Miami to the Dry Tortugas. The coral reef community is an almost continuous reef tract and parallels the emergent Keys for 356 km, arcing in a southwesterly direction before terminating west of the Dry Tortugas. An outer-reef tract lies east and south of the Keys at a distance of 4.8 to 11.3 km. Because the Upper and Lower Keys are protected from the direct flow of water from the Gulf of Mexico, they are considered to have greater reef development than the Middle Keys.

The NMSP has managed sanctuaries along the coral reef tract in the Florida Keys since 1975. The Key Largo National Marine Sanctuary was established in 1975 to protect 353 km^2 (103 square nautical miles) of coral reef habitats stretching along the reef tract from just north of Carysfort Lighthouse to south of Molasses Reef, offshore of the Upper Keys. In 1981, the 18 km^2 Looe Key National Marine Sanctuary was established to protect the very popular Looe Key Reef located off Big Pine Key in the Lower Keys. These two offshore National Marine Sanctuaries were, and continue to be, managed very intensively. The installation of mooring buoys to protect the reefs from anchor damage, educational programs, research and monitoring programs, and various resource protection programs, including interpretive law enforcement, were concentrated in these two marine protected areas. Both sites were in federal waters. Since these two sanctuaries are between 5 and 7 km offshore, the health of these coral reef resources has been affected by land-based sources of pollution and nutrients. Managing these two sites was like attempting to manage islands in the middle of the ecosystem. Obviously, the major threats came from outside the boundaries of the sanctuaries**.** In order to be successful at management, an ecosystem approach had to be implemented.

By the late 1980s, it became evident that a broader, more holistic approach to protecting and conserving the health of the coral reef resources had to be implemented. Regardless of the intensity used in managing small portions of the coral reef tract, sanctuary managers were witnessing declines in water quality and the health of corals from a wide range of causes. The more obvious causes of decline were point-source discharges, habitat degradation due to development and over-use, and changes in reef fish populations due to over-fishing. Clearly, less obvious sources of decline were affecting the health of the coral reefs and these had to be identified. These impacts were occurring at the local, regional and global scales.

GLOBAL AND REGIONAL CHALLENGES

Ten percent of the world's coral reefs are considered to be lost beyond recovery and the remaining coral reefs, especially those near population centers, are in a state of decline. However, coral reefs are not the only marine ecosystem or marine resource that is in a state of alarming decline. Coral bleaching, massive algal blooms, pollution, habitat destruction, over-fishing, introduction of invasive marine organisms, ocean dumping, coastal development, and global climate change are all affecting the health of the world's oceans. As a result, the economies that depend on a healthy ocean environment are being affected on local, regional, and global scales.

For decades we have taken our bounties from the oceans: tapped into their vast reservoir of resources; used their surfaces to move our commerce from port to port, coast to coast and continent and continent; and replaced vital coastal and marine habitats with facilities and development designed to attract ocean-loving people to our shores. Now we are witnessing the results of past actions by way of polluted waters, collapsing fisheries, loss of critical coastal and marine habitats, harmful algal blooms, hazardous stormwater runoff, and introduction of exotic marine species.

Among our mistakes has been the failure to treat our oceans as a finite resource. For generations, we have honestly assumed that our oceans will always be capable of supplying our needs, whether they are economic or spiritual in nature. We have always taken the quality of life given by our oceans for granted. However, in a few brief decades we have witnessed advancing technology collide with the ability of marine life to sustain itself.

SOCIAL AND ECONOMIC SIGNIFICANCE

In the USA we have witnessed a huge increase in the migration of our population to our shoreline. Today, more than 50% of the USA population lives within 80 km of a coast, and 3600 people join them daily as coastal residents. On a global scale, two-thirds of the world's more than 5.5 US billion people live within 80 km of the coast.

We are only beginning to realize the economic importance of our oceans as we watch our coral reefs suffer from coral bleaching, lose critical commercial fisheries, witness the decline of water quality, puzzle over mysterious fish die-offs, cope with coral diseases, monitor toxic algal blooms, and assess the impacts of exotic marine species. Today, one out of every six jobs in the USA is related to the oceans. In 1995, the USA fishing industry added more than $US20 billion to the economy, while coastal tourism generated more than $54 billion. For example, 3 million tourists visit the Florida Keys on an annual basis and stay an average of 13.3 million visitor-days. While in the Keys, the tourists spend $1.2 billion each year. Their favorite activities are snorkeling and diving on the living coral reefs, fishing and simply enjoying the environment.

The USA coastal tourism and recreation industries are the largest and fastest-growing economic segments of the USA service industry. Travel and tourism contribute tax revenues in excess of $58 billion a year, with $7.5 billion of that generated by foreign visitors. Beaches are the leading tourism destination in the country, followed by national parks and historic sites. In 1997, the USA Environmental Protection Agency (EPA) reported that coastal and marine waters support 28.3 million jobs, generate $54 billion in goods and services, contribute $30 billion to the USA economy through recreational fishing and provide a recreation destination for 180 million Americans each year. Miami Beach is an excellent example of just how much good beaches mean. There was no beach left by the mid 1970s as a result of erosion. Beginning in the late 1970s, a beach renourishment program was initiated, and beach attendance increased from 8 million in 1978 to 21 million visitors just five years later.

SANCTUARY DESIGNATION

The United States Congress designated the Florida Keys National Marine Sanctuary (FKNMS), which is 9600 km ^{2} in size, in 1990 (Fig. 1). The Sanctuary encompasses all of the waters surrounding the islands of the Florida Keys up to mean high tide. Some of the marine communities included in the Sanctuary are mangrove islands, lush seagrass beds, productive hard bottom, a variety of patch-reef habitats, offshore spur-and-groove coral-reef formations and deep coral reefs. The Sanctuary encompasses an estimated total 325 km² of coral reef, 143 km² in State of Florida territorial waters (< 5 km from shore) and the remaining 182 km² federal–waters (>5 km from shore).

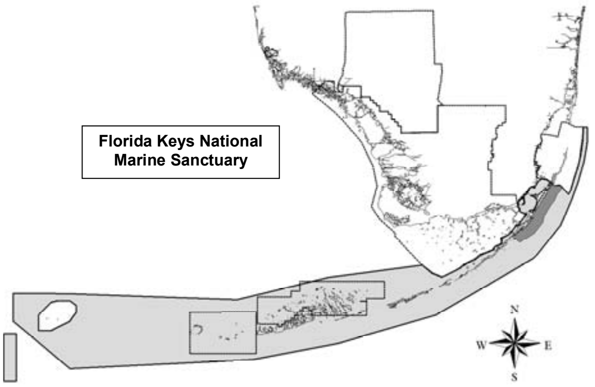

Fig. 1. Shaded area indicates the 9600 km² boundary of the Florida Keys National Marine Sanctuary.

With the designation of the Sanctuary, the entire coral reef tract of the Florida Keys was afforded certain levels of protection. Oil and hydrocarbon exploration, mining, and large shipping traffic are excluded from the Sanctuary. Anchoring on corals in shallow water is prohibited, as is touching coral, collecting living or dead coral, and harvesting "live rock", a product of the aquarium trade. The Sanctuary has the authority to address discharges within its boundary, as well as potential pollutants that originate from outside the Sanctuary, offering protection of water quality that is critical for coral reef health.

The purpose of the Sanctuary is to protect the unique marine resources found within the Florida Keys and to manage human use of these resources. The management plan for the FKNMS contains a variety of management tools to protect and sustain the marine environment of the Florida Keys.

Sanctuary management tools

The Sanctuary's management plan was implemented in 1997. That plan was developed in an integrated process using various stakeholder groups, including a Sanctuary Advisory Council and all of the local, State, and federal agencies that have a management role in the Florida Keys. General categories for the management programs are

- Research and Monitoring,
- Education and Outreach,
- Volunteerism,
- Enforcement,
- Threat Reduction Measures, and
- Marine Zoning.

The individual components of these programs are far too comprehensive to cover fully in this paper, but a brief description follows.

Research and monitoring

To monitor changes occurring in the marine environment of the Florida Keys, the Sanctuary has implemented a comprehensive research and monitoring program. The goal of this program is to establish baseline information on the various components of the ecosystem and ascertain cause-and-effect relationships. In this way, research and monitoring can ensure the effective implementation of management strategies using the best available scientific information.

Many groups, including local, State, and federal agencies, public and private universities, private research foundations, environmental organizations, and independent researchers, conduct research on the coral reef environment. The Sanctuary facilitates and coordinates research occurring within its boundaries by registering researchers through a regional permitting system, recruiting institutions to carry out priority research activities, overseeing data management, and disseminating relevant findings to the scientific community and to the public.

Monitoring within the Sanctuary occurs at a number of levels. The objectives of the monitoring program are to establish reference conditions for biological communities and water quality within the Sanctuary so that the effectiveness of management actions, specifically the non-consumptive zones, can be evaluated over time.

The most comprehensive, long-term monitoring program underway in the Florida Keys is conducted through the Water Quality Protection Program (WQPP), funded by the USA EPA through the authority of the *Sanctuary* Act. The WQPP and its associated monitoring program began in 1994 and consist of three components: water quality, corals and hardbottom communities, and seagrasses. The status of reef fishes, spiny lobster, queen conch, benthic cover, and algal blooms are monitored Sanctuary-wide as well through NOAA funding.

In addition to fixed-station monitoring occurring under the WQPP, the effects of no-take management, which began in 1997 through the implementation of 23 discrete marine reserves, are specifically being monitored through a Zone

Monitoring Program (ZMP). The goal of the ZMP is to determine whether the no-take zones are effective in protecting marine biodiversity and enhancing human values related to the Sanctuary. It is the year 2002. The ZMP is a three-level program that monitors changes in ecosystem structure (size and number of invertebrates, fish, corals, and other organisms) and function (such as coral recruitment, herbivory, predation). Measures of effectiveness will include the abundance and size of fish, invertebrates, and algae, as well as economic and aesthetic values of Sanctuary users and their compliance with regulations. Human uses of zoned areas are also being tracked.

Education and outreach

The primary management tool used in the 13 National Marine Sanctuaries is education and outreach. Increasing public awareness and understanding through education is critical to achieving resource protection and stemming many of the ocean problems described above. Aquatic protected areas such as National Marine Sanctuaries provide excellent settings in some of the most significant and fascinating marine and coastal environments in the USA.

By reaching the recreational visitors to the coastal or marine environments with educational and outreach messages, we are able to spread our messages across the nation, and indeed the world. However, it is also important that we reach our coastal residents with the same educational and outreach messages. For that purpose, the FKNMS has developed an informal education program that comprehensively targets both visitors and residents.

Our audience is the more than 80,000 year-round residents in the Keys, the 50,000 winter residents, and the 3 million visitors who spend 13.3 million visitor-days snorkeling, scuba diving, fishing, or relaxing in the tropical environment of the Florida Keys.

Impacts to the resources of the Florida Keys are numerous, including water quality degradation, habitat destruction, over-fishing and increasing human pressures on a finite, fragile ecosystem whose balance began to topple in the 1950s. Each one of these threats to the marine ecosystem of the Florida Keys requires education and outreach programs that target specific audiences. For example, many of the impacts to the shallow-water resources of the Keys come from boating activities. Whether it is propeller-scarring in the seagrass beds or running aground on fragile coral reefs, much of the habitat destruction we are witnessing is the result of poor or inexperienced boat operation. In the past ten years alone, boater registration has increased 60% in the Florida Keys. There is one boat for every two households in the Keys. This does not include the tens of thousands of boats that are brought by trailer into the Keys by visitors each year.

Some of the challenges we face in educating residents, visitors and the wider public are as follows:

- There is no single point of entry to the Sanctuary;
- There are large numbers of users;
- There are diverse, multilingual residents and tourists; and
- Resource damage occurs from both direct and indirect impacts.

These challenges are not unlike many of those facing other aquatic protected areas around the nation or the world, for that matter. The goal of our education and outreach program is to meet and overcome these challenges with innovative and creative educational tools that increase the public's understanding of the marine environment. This will develop a more informed public who appreciate and use the marine environment for recreational, commercial or aesthetic purposes, recognizing their full impact on those resources.

The management plan for the Sanctuary contains an Education and Outreach Action Plan that uses a variety of tools to convey critical information to the various audiences. These tools are

- Community-Based,
- School-Based,
- Partnership-Based,
- Technology-Based,
- Product-Based, and
- Media-Based.

A description of these various programs can be found in the Sanctuary's final management plan.

Volunteers

The Sanctuary's volunteer program was established through a partnership with a non-governmental organization, The Nature Conservancy. Partnerships with the State of Florida, academic institutions and other non-governmental organizations have dramatically expanded the work begun by Sanctuary staff. With limited staffing and financial resources, the Sanctuary has been far more effective in carrying out some management programs because of the commitment of residents and visitors in seeing conservation work being done. For example, more than 120,000 volunteer-hours were donated to the Sanctuary between 1996 and 2000. This is equal to $1.8million dollars in contributions, based on a national figure that calculates the value of volunteer-hours.

Enforcement

Although National Marine Sanctuaries rely largely on compliance with Sanctuary regulations, the history of the Sanctuary program in the Florida Keys has required a major commitment to enforcement activities by NOAA. When Congress expanded the Sanctuary boundary in 1990, it became abundantly clear to Sanctuary managers that a major enforcement presence would have to be maintained in order to protect and conserve Sanctuary resources. Sanctuary enforcement in the Florida Keys has traditionally been accomplished through a cooperative agreement between NOAA and the State of Florida. The State continues to be the primary enforcement arm for the Sanctuary. NOAA provides 100% of the funding for enforcement activities in the Sanctuary to the Florida Fish and Wildlife Conservation Commission. There are 17 State-certified law-enforcement officers assigned to the Sanctuary enforcement team. In addition, NOAA's Office of Law Enforcement and the USA Coast Guard also provide enforcement support to the Sanctuary.

Threat reduction measures

The *Florida Keys National Marine Sanctuary and Protection Act* contains very specific prohibition of certain uses such as the operation of vessels longer than 50 m (164 feet) within an Area to be Avoided (ATBA) established around Sanctuary waters, and a prohibition on oil and hydrocarbon exploration and mining within the Sanctuary. The Act also contains very precise directions from Congress on the development of a WQPP by EPA and a comprehensive management plan by NOAA.

There have been significantly positive results since Congress restricted vessel operation within ATBA surrounding Sanctuary waters. The ATBA has been very effective at decreasing the number of major ship groundings on the coral reefs of the Florida Keys. Prior to 1990, there was a major ship grounding (>50m in length) nearly every year. After the ATBA took effect in 1990, 6 years elapsed before there was a major ship grounding, and only 2 have occurred since 1990.

In addition, the Sanctuary and adjacent waters have been approved as a designated Particularly Sensitive Sea Area (PSSA). This designation has to be approved by the International Maritime Organization and exists for only two other areas in the world. PSSA designation, although not accompanied by any additional rules or regulations, serves to elevate international recognition of the sensitivity of the marine environment of the Florida Keys to any catastrophic events, such as oil spills or release of hazardous materials.

Congress recognized the decline in the nearshore water quality of the Florida Keys when it designated the Sanctuary. Legislators authorized the EPA to work with the State and NOAA to develop a WQPP. Even before the implementation of the final plan in 1997, EPA and its partners had completed the WQPP. EPA incorporated the components of the WQPP into the Water Quality Action Plan contained in the Final Management Plan (1996). The EPA and its partners have continued to implement critical projects identified in the Plan. The purpose and active role of the WQPP have been to recommend priority corrective actions and compliance schedules addressing point and non-point sources of pollution to restore and maintain the living coral reefs and other critical marine life in the Sanctuary.

The WQPP consists of four interrelated components: (*1*) corrective actions that reduce water pollution directly by using engineering methods, prohibiting or restricting certain activities, tightening existing regulations, and increasing enforcement; (*2*) monitoring that includes a comprehensive, long-term water-quality monitoring program designed to provide information about the status and trends of water quality and biological resources in the Sanctuary; (*3*) research/special studies that are designed to identify and understand cause-and-effect relationships involving pollutants, transport pathways, and biological communities of the Sanctuary; and (*4*) public education and outreach programs designed to increase public awareness of the Sanctuary, the WQPP, and pollution sources and impacts on Sanctuary resources.

Other threat-reduction measures include the implementation of Sanctuary regulations under the authority of the *National Marine Sanctuary Act* to protect and conserve Sanctuary resources. The regulations are divided into Sanctuary-wide regulations and regulations that apply to specific marine zones in the Sanctuary. The Sanctuary-wide regulations are focused on decreasing the level of habitat destruction in the Keys and addressing water-quality issues; they prohibit anchoring on corals in shallow water, touching coral, collecting living or dead coral, and taking "live rock". Operating vessels in such a manner as to strike or otherwise injure coral, seagrass or other attached marine life is prohibited. The Sanctuary has the authority to address discharges within its boundary, as well as potential pollutants that originate from outside the Sanctuary, offering protection of water quality that is critical for coral reef health and vitality.

In addition to Sanctuary-wide regulations that address direct and indirect impacts to coral reef resources, regulations specific to five types of marine zone were implemented in July 1997. At that time, the Florida Keys National Marine Sanctuary implemented the first network of marine zoning for a National Marine Sanctuary in the USA. Three of the five zone types, Ecological Reserves, Sanctuary Preservation Areas, and Special Use / Research-only Areas include a total of 24 individual "no-take" or "fully-protected" areas that have been established within the Sanctuary to protect critical habitat, preserve a diversity of species, and relieve pressure in heavily used coral reef areas. These areas constitute 6% of the total area of the Sanctuary, or 10% of the coral reef community. Stringent restrictions on taking, removing, etc. marine life and harming natural resources are in place in these zones to ensure their long-term health. Lobstering, fishing, spearfishing, shell collecting, and other consumptive activities are prohibited in these areas. There is a more detailed discussion of the marine zoning within the Sanctuary below.

Other threat-reduction measures have included the implementation of a Sanctuary-wide mooring-buoy program, developed in the FKNMS by Sanctuary Biologist John Halas in 1981. This simple, yet effective tool for reducing anchor damage to coral reefs and seagrass beds was later implemented in the Looe Key National Marine Sanctuary (1984) and eventually spread to other parts of the Keys. Sanctuary staff worked with Reef Relief, a grassroots conservation group in Key West, and two other grassroots groups in the Keys to install mooring buoys at many popular dive sites along the reef tract. Although mooring buoys are excellent management tools, it is important to realize that other management programs must accompany a mooring-buoy program, such as education, outreach, research and monitoring. When the FKNMS was designated, the Sanctuary incorporated mooring buoys previously installed by other organizations in Key West, Marathon and Islamorada, expanding the number of buoys managed by the Sanctuary from 175 to more than 400. Besides mooring buoys, the Sanctuary staff have installed and maintain 109 yellow boundary buoys (30" diameter) and 120 Wildlife Management Area boundary buoys to mark the marine zones.

In addition to mooring buoys, the Sanctuary staff work closely with other agencies in implementing a Waterway Management Action Plan. Channel marking in the Sanctuary falls primarily under the jurisdiction of the United States Coast Guard (USCG) and the State of Florida. However, Monroe County, in which the Sanctuary is located, manages a large number of navigation aids that it has installed in Keys waters. The County uses boating-improvement funds that come from the registration of vessels in Monroe County to install navigation aids in areas identified in their Channel Marking Master Plan. All channel markers and navigation aids have been inventoried; approximately 600 aids to navigation in the Florida Keys are maintained and referenced in a GIS database. A boat-access survey of all Monroe County marinas, boat ramps and docking facilities has been completed and entered into a marine facilities GIS database.

The Sanctuary worked with the USCG, the owners of the *M/V Contship Houston*, and the Key West Propeller Club to place eight Racon beacons on navigational aids along the reef tract from Loggerhead Key in Dry Tortugas National Park to Fowey Rocks in the northern end of Biscayne National Park. These beacons send a signal that is picked up on the radar screens of passing ships, warning them of the coral reef tract. The Sanctuary used its authority to negotiate with the ship owners to have them purchase 10 of these highly effective beacons.

Marine zoning

Australia has led the world in the application of marine zoning to protect and conserve marine resources while those resources are used by various groups. Following Australia's example, Sanctuary managers have attempted to balance protection of Sanctuary resources with their continued use through the implementation of a comprehensive network of marine zones. Marine zoning is the setting aside of areas for specific activities, which allows the balancing of commercial and recreational interests with agency mandates to protect marine resources. Comprehensive marine zoning is a fairly recent concept in the management of marine protected areas within the USA, but has been successfully implemented internationally for decades.

The coral reefs of the Florida Keys have been the focus of consumptive or extractive activities since before the invention of SCUBA in the 1940s. Naturally, these activities have increased in intensity over the past few decades, and today many Keys residents simply talk about what it used to be like in the "old days." Stories of beds of queen conch, rafts of sea turtles, huge schools of tropical fish, grouper, snapper and so many lobster all you had to do was wade out from shore for them are common. The final plan for the Sanctuary includes a marine zoning plan that will make it possible for the coral reef to be like that again.

The marine zoning plan was one of the most controversial elements of the planning process, yet setting aside portions of the coral reef community as Ecological Reserves will allow these areas to return to what they were before man started disturbing them. Compared with the overall size of the Sanctuary, which is 9600 km^2, the areas in the final plan are small, but they are necessary to accomplish the overall goals of the Sanctuary.

Although there was large support for marine zoning from some groups during the development of the Sanctuary's management plan, it was the most controversial management tool considered. The topics of greatest concern in establishing the marine zoning plan were the proposed locations, sizes and allowable uses.

In the early days of public consultation on the draft marine zoning plan, Sanctuary officials were hung in effigy by concerned commercial fishermen and other groups who opposed what NOAA was proposing. A large opposition movement was massed between 1992 and the implementation of the Final Management Plan in 1997.

Between the release of the draft management plan in 1995 and the Final Plan, NOAA reduced the amount of area set aside as "no take" or "fully protected" in the marine zoning plan from less than 6% to less than 1%. However, Sanctuary managers did make it clear in the Final Plan that a process would be developed to establish an ecological reserve in the western extent of the Sanctuary.

In July 1997, the FKNMS implemented the first network of marine zoning for a National Marine Sanctuary in the USA. Five types of zones were implemented at that time, with different objectives and regulations. A brief description of the zones follows.

Sanctuary Preservation Areas (SPA). All activities that do not result in removal of marine life or damage to the resources are allowed in these areas. Activities that are prohibited in the SPAs include spearfishing, shell collecting, tropical fish collecting, fishing, and other activities that result in the taking of marine life by divers, snorkelers, and fishers. In addition, direct physical impact to corals in these areas is prohibited. In an effort to reduce socio-economic costs from the SPAs, regulations allow catch-and-release fishing by trolling in four of the SPAs: Conch Reef, Alligator Reef, Sombrero Key, and Sand Key.

Special-use research only areas. There are only four special-use areas in the Final Management Plan: Conch Reef, Tennessee Reef, Looe Key (patch reef), and Eastern Sambo Reef. These are all designated as research-only areas. No person may enter these areas except as specifically authorized by a valid permit.

Ecological Reserves (ER). All activities that do not result in removal of marine life or damage to the resources are allowed in these areas. Spearfishing, shell collecting, tropical fish collecting, and other activities that result in the harvest of marine life by divers and snorkelers, and fishing activities will be prohibited in this zone type. In addition, direct physical impact to corals and vessel discharges are restricted.

Wildlife Management Areas (WMA). There are 27 WMAs established in the Final Plan. Twenty of these areas fall under the jurisdiction of the US Fish and Wildlife Service (USFWS), and Sanctuary regulations have been established to complement the USFWS criminal sanctions with Sanctuary civil penalties. Public-access restrictions in these areas include idle speed only/no wake, no access buffer, no motor, and closed.

Existing Management Areas (EMA). Out of the total 19 existing management zones, 13 are administered by the State of Florida Department of Environmental Protection, 4 by the US Fish and Wildlife Service, and 2 by NOAA. Managing these areas within the Sanctuary may require additional regulations or restrictions to provide complete resource protection. These additional management needs will be developed and implemented in cooperation with the relevant agency.

The marine zoning Plan provides a very common-sense approach to focusing protection in small critical portions of sensitive habitats, while not restricting activities any more than necessary. For example, the 18 SPAs that are in the final plan protect more than 65% of the shallow spur-and-groove reef habitat, while capturing approximately 80% of the year-round diving activity. These Areas displace very few commercial and recreational fishermen and their "no take or consumptive activity" status will lead to resource enhancement of the coral reefs. By making these Areas "no take or consumptive activity" areas, the visiting divers are directed to reef habitat where their activity will have less impact. Approximately 6% of the Sanctuary is designated as "no take or extraction".

Three of the zone types, Ecological Reserves, Sanctuary Preservation Areas, and Special Use / Research-only Areas, include a total of 24 individual "no-take" or "fully-protected" areas that have been established within the Sanctuary to protect critical habitat, preserve a diversity of species, and relieve pressure in heavily used coral reef areas. Stringent restrictions on harvesting marine life and harming natural resources are in place in these zones to ensure their long-term conservation. The 27 WMAs restrict vessel operation and provide resource protection to shallow-water habitats, including seagrass flats. These Areas also serve to enhance the experience of catch-and-release fishermen. The EMAs are necessary to recognize the continued authority of the agencies overseeing these protected Areas.

Most of the smaller zones (Sanctuary Preservation Areas) are located along the offshore reef tract and encompass the 65% of the most heavily used spur-and-groove coral formations.

Ecological Reserves are the most significant type of marine zone in the Sanctuary. They are the largest "fully protected" areas. These encompass large, contiguous diverse habitats and are designed to preserve biodiversity, provide spawning, nursery, and residence areas for marine life, protect habitats and species not covered by existing fishery management regulations, and allow areas to remain in or return to a natural state. The Sanctuary has two Ecological Reserves. The 30.8 km^2 Western Sambo Ecological Reserve protects offshore coral reefs, as well as all other habitats, including mangrove fringe, seagrasses, and productive hardbottom reefs.

In July 2001, after a three-year collaborative design-and-planning process, the Tortugas Ecological Reserve (518 km^2) was established to increase the Sanctuary's network of marine zones outlined in the management plan. This concluded a 10-year management planning process during which many lessons were learned. This new Reserve, in the westernmost portion of the Florida Reef Tract, conserves important deepwater reef resources and fish communities unique to this region. The Tortugas Ecological Reserve preserves the richness of species and health of fish stocks in the Tortugas and throughout the Florida Keys, ensuring the stability of commercial and recreational fisheries. Restrictions on vessel discharge and anchoring were implemented in this zone to protect water quality and habitat complexity. It is expected that the Reserve's geographical isolation will aid scientists in distinguishing between natural and anthropogenic changes to the coral reef environment.

The Tortugas Ecological Reserve is also significant because it adjoins a proposed 157.8 km^2 Research Natural Area in the Dry Tortugas National Park, a zone where shallow seagrass, coral, sand, and mangrove communities will be conserved. Together, the Sanctuary's Tortugas Ecological Reserve and the National Park's Research Natural Area fully protect nearshore to deep reef habitats of the Tortugas region and form the largest, permanent marine reserve in the US A.

LESSONS LEARNED

There were many "Lessons Learned" during the process to develop and implement a marine zoning plan for the Sanctuary, including the following:

- Establish goals and objectives for the "reserve" at the beginning;
- Agree on the ground rules;
- Don't predetermine the location or size of a "no take" area;
- Do not begin the process with a specific percent area to be set aside;
- Include representatives of all stakeholder groups;
- Don't assume that one commercial fisher represents all aspects of commercial fishing;
- Don't assume that one conservation member speaks for all conservation interests;
- Don't leave out representatives from the general public;
- Include all affected fishery managers and agency representatives;
- Involve scientists, but not just fisheries biologists – ecologists and oceanographers must also be included;
- Make sure the process is open and flexible;
- Make sure the public has opportunities to engage in the process;
- Strive for unanimous support or the highest level of consensus; and
- Allow the stakeholders to help guide the process.

Planning a no-take reserve must be a bottom-up procedure that includes a well balanced group of stakeholders from the local community. Models or textbook approaches can use the most recent science or theory available but will not work if you exclude the local experts. The group must include those who make their living on the water, as well as those who have local conservation experience. For example, accord commercial fishers the same status as PhD scientists; after all, commercial fishermen have "PhDs in commercial fishing." Stacking a working group with outsiders raises suspicion and can lead to failure.

Furthermore, the procedure for selecting participants is important. The planning process must include those who will be respected by their peers as spokespersons for the stakeholder group. I cannot overemphasize the importance of this step. The selection process for the participants and the make-up of the working group must be viewed as balanced and representative if the process is to have any chance of gaining public confidence. –The process is doomed to failure if individuals with extreme, uncompromising viewpoints are included.

Striving for balance does not mean achieving equal numbers of constituent groups, for example, one commercial fisher and one conservationist. However, make sure all aspects of the fishing and conservation community have representation in the group. Do not try to stack the membership of a working group in favor of a particular viewpoint. Both the participants and general public will see through the façade and the process will lose credibility. Don't hesitate to include individuals with differing viewpoints. Let the science and the balanced, integrated approach to establishing a reserve stand on their own merit. Know that reasonable, knowledgeable, and experienced people will make good decisions when provided with good science.

Establish a high level of trust among the group as soon as possible. Participants must be willing to respect differing opinions. The idea is to empower those who know the resources best, and who have some vested interest in the reserve's success. However, you must be willing to seriously consider their advice and demonstrate how the experience and opinions of your local experts have influenced the design of the reserve.

Avoid allowing the group to begin discussions by proposing boundaries or arguing about the percentage of an area that should be designated no-take. Such discussions will polarize the group from the start. Instead, begin by providing the group with the best available scientific and socio-economic data about the area.

Oceanographers can explain the current patterns so that the participants can see for themselves the mechanisms for larval distribution. Geologists can explain the long-term perspective of natural forces affecting the area. Ecologists can discuss special natural features, and fisheries biologists can explain reproductive patterns in marine organisms. Try to establish long-term trends, which invariably show declines in many regions. Present all of this information as if you were building a geographical information system, layer by layer.

The most important layer is the various "uses" of the region. Find out from the experts where the fish spawning aggregations are. Learn about the seasonal and annual movement of fish and other marine life. Learn where the fishers work, and ask them what areas they think are important and worthy of reserve protection.

Ask scientists, conservation groups, and non-extractive users of the area these same questions. The idea is to start developing a joint vision of the special areas that should be considered for protection.

It is important to conduct a thorough socio-economic assessment. Fisheries economists must collect data at the most detailed scale possible. Incomplete or inaccurate information will fuel opposition from user groups. Thorough consideration of socio-economic factors can build support for the reserve and boost the confidence of user groups in the process.

SUCCESSFUL IMPLEMENTATION OF MARINE ZONING

The success of implementation of a marine zoning plan depends on the effectiveness of several other management programs. Those are

- Marking boundaries on charts, with buoys and through inclusion in DGPS units,
- Education and outreach,
- Monitoring and research on zone effectiveness, and
- Enforcement.

Marking boundaries. Successful implementation will be best achieved if the public can voluntarily comply with regulations. This requires clearly marking the protected areas on navigation charts or marking the boundaries with buoys. Use of both these tools leads to even higher compliance rates. Additionally, when possible, facilitate the inclusion of marine zoning boundaries in the Differential Geographical Positioning Systems (DGPS).

Education and outreach. The majority of the general public will comply with marine zone regulations if they are aware of them. It is critical to include education and outreach programs designed to reach the general public before they have a chance to harm or damage the resources.

Marine zone monitoring and research. Results from the Sanctuary's zone monitoring program indicate that three years after zone implementation, some heavily exploited species exhibit increased differences in abundance and size. Specifically, legal-sized spiny lobsters continue to be more abundant in Sanctuary Preservation Areas than in reference sites of comparable habitat. The average size of lobsters is larger and remains above the legal minimum size limit in the no-take areas, whereas lobsters found at reference sites have remained below legal size. The mean size of lobsters within the Western Sambo Ecological Reserve has been significantly larger than in reference areas in both the open and closed fishing seasons. Additionally, catch rates (number of lobsters per research trap) are higher within the Ecological Reserve than within two adjacent fished areas at all times of the year.

Overall, a high degree of variability has been documented with regard to reef-fish abundance and size between no-take areas and reference sites. However, as would be expected with the added protection of no-take management, some species have shown increased abundance over time.

Enforcement. One of the major site-selection criteria identified in the design of the Tortugas Ecological Reserve was "enforceability." All groups, ranging from commercial fishermen to conservation organizations, ranked enforceability as a major criterion in selecting sites, as well as leading to their long-term success. This includes actions such as selecting boundary lines along latitude and longitude lines and acquiring enforcement staff and resources necessary for them to do their job. Although the majority of the public will comply with regulations, a small percentage of chronic violators will lead to lower levels of compliance and a loss of confidence by the general public, if enforcement is inadequate.

CONCLUSIONS

Marine zoning is critical to achieving the Sanctuary's primary goal of resource protection. Its purpose is to protect and preserve sensitive components of the ecosystem by regulating within the zoned areas, while facilitating activities compatible with resource protection. Marine zoning ensures that areas of high ecological importance evolve in a natural state, with minimal human influence, while allowing sustainable use of Sanctuary resources. Marine zoning can be effective at protecting diverse habitats, and preserves important natural resources and ecosystem functions.

Success in stemming the decline of our oceans depends on our collective understanding of the concept of sustainability. We must remind ourselves that our generation cannot use up the resources that are important to support the economy and environment that will be inherited by future generations. The use of marine zoning takes the guesswork out of managing and maintaining natural systems in the marine environment. We hardly understand the biology and ecology of many species of marine life that we allow to be taken; yet the quantity and quality of marine resources continue to plummet around the world.

With the Great Barrier Reef, Australia has the enormous luxury of geographical space. Other parts of the Indo–West Pacific are equally massive in geographical extent. However, none of us have the luxury of time on our side. A broad range of impacts is affecting coral-reef environments, and we must set some areas aside where we can determine their effects by eliminating the impacts we can control.

"It is important to scientific study and to the health and sanity of man, that there be preserved some unique areas … to observe nature's continuing evolution; … the grandeur and peace of nature." *Samuel H. Ordway, Jr.*

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Consultation with Indigenous Communities Regarding Fish Habitat Areas – The Cape York Peninsula Experience

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Abstract

Fish Habitat Areas (FHA) are declared by the Queensland Fisheries Service (QFS) as part of the ongoing identification, management and protection of critical fish habitats in Queensland. The Cape York Peninsula region is biologically one of the most diverse areas in Australia. With one of the highest species diversities of marine vegetation in the world, the area supports important traditional, recreational and commercial fisheries. However, in relation to the size of Cape York Peninsula, it has very few declared FHAs. In 1999, QFS began a program to investigate the declaration of three new FHAs within the Cape York Peninsula region. Standard QFS FHA consultation procedures and timeframes formed the basis for initial consultation. However it quickly became evident that effective communication with indigenous communities required departure from 'standard' time frames, information delivery techniques and information gathering processes. Case studies from the Cape York Natural Heritage Trust project are presented to illustrate the highlights and challenges of working with indigenous communities, lessons learnt along the way, subsequent changes to FHA procedures and new initiatives that have been developed.

Keywords: fish habitat areas, indigenous, consultation, Cape York Peninsula, aquatic protected areas

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Fish Habitat Areas

A Fish Habitat Area (FHA) is declared over a precisely defined area of key fish habitats for the purpose of maintaining existing and future fishing activities and protecting the habitats upon which fish and other aquatic fauna depend. A FHA protects the integrity, structure and fish habitat values of all habitats (including shallow-water banks and channels, seagrass, mudflats, seagrass and mangrove communities) within the boundary of the declared area (Zeller and Beumer 1996). FHAs form an important component of the ongoing protection and management of fisheries resources and wetland habitats in Queensland. The Areas are declared with the specific intent of ensuring the continuation of productive recreational, commercial and traditional fisheries in a region.

The Queensland Fisheries Service (QFS) manages all declared FHAs in Queensland. Any proposed development-related activities that require works within, or alteration to a Fish Habitat Area, must be assessed by the QFS in accordance with management policy. The outcome of this assessment will identify impacts and determine whether the proposed activity can or cannot proceed within the FHA (Zeller and Beumer 1996).

A FHA may be declared as either 'A' or 'B' management level, or a combination of the two (McKinnon *et al.*, 2003). The two-tiered management approach recognises that important fish habitats occur within locations

- where very strict FHA management arrangements can be achieved, but also
- where existing or planned uses of some Areas or their surrounds require a more flexible management approach.

Although normal community use and activities (including legal fishing activities) are not restricted by FHA management, any works or activities requiring the disturbance of habitats within a FHA require a specific permit under the provisions of the *Fisheries Act 1994* (Zeller and Beumer 1996).

An individual FHA is nominated and declared on the basis on its specific habitat and fisheries values, and then each FHA extends the Statewide network of FHAs. The Areas combine to help protect the regional viability of Queensland's fish, mollusc and crustacean stocks by supporting adjacent and offshore fishing grounds (by means of primary production inputs, protection of nursery areas and feeding grounds, and protection of spawning locations). Declared FHAs form an integral part of the total coastal-planning process for future fish-habitat protection and are gazetted following appropriate consultation (Beumer *et al.* 1997).

The selection of new FHAs was initially reactive and driven by the need to provide increased protection of high-quality fish habitats within areas that were already subject to ongoing development pressures (Olsen 1977). The east coast of Queensland has been the major focus for FHA declaration over the past 30 years, with 95% of the FHA network, by area, being within this section of the coast (McKinnon *et al.* 2003). This is directly related to the higher population and development pressures within these coastal areas and to the primary objective of the FHA network to protect a proportion of the remaining fish habitats from these pressures (McKinnon *et al.* 2003).

There are 75 declared FHAs distributed along the Queensland coast from Currumbin Creek near the Queensland / New South Wales border to Eight Mile Creek near Burketown in the Gulf of Carpentaria. These 75 FHAs cover an area of more than 740 000 hectares of fish habitats. Within the Cape York Peninsula region, only eight FHAs have been declared, and these cover an area of approximately 97 000 hectares. These eight FHAs were all declared in the 1980s based on their extensive habitats, value to commercial and recreational fishers and diverse vegetation (Beumer *et al.* 1997).

CAPE YORK PENINSULA

Cape York Peninsula is a diverse and important region of North Queensland, Australia (CYRAG 1996). It covers approximately 137 200 sq km of land and seas and has a population of about 25 000 people. Indigenous people form over half of the area's total population and reside in ten Aboriginal settlements (O'Fairchaellaigh 1999). Cape York Peninsula is culturally, ecologically and economically important (CYRAG 1996).

The Cape York Peninsula Land Use Strategy (CYPLUS) was formed in 1992 to provide a vehicle for the establishment of regional land and land-related resource-use objectives within the context of Australian and Queensland Ecologically Sustainable Development Policy. The Strategy is a blueprint for sustainable land use and economic and social development on Cape York Peninsula and is based on a three-stage process – data collection and analysis, strategic development, and implementation and evaluation (CYRAG 1996). It is currently in the final stages.

Aboriginal people's affiliation with land and seas has been identified and recognised by european people and governments. This affiliation results from aboriginal ownership, occupation and management of land and sea country. Recognition of indigenous interests in sea country has steadily increased over the past 20 years and began with the recognition of 'traditional hunting' within the Great Barrier Reef Marine Park (Smyth 2000). The QFS also recognises the importance of customary fishing and Section 14 of the Fisheries Act 1994 reflects this. This section of the *Act* recognises that aboriginal people may take, use or keep fisheries resources or fish habitats under aboriginal tradition.

CAPE YORK NATURAL HERITAGE TRUST PROJECT – FISH HABITAT AREA ASSESSMENT AND DECLARATION ON CAPE YORK PENINSULA

In 1999 the Department of Primary Industries, Fisheries received Natural Heritage Trust (NHT) funding to assess and declare three new FHAs on Cape York Peninsula. The three candidate areas were selected from earlier broad-scale marine-vegetation mapping conducted through CYPLUS, in which the areas were considered against FHA selection criteria (Danaher 1995). The three areas, the Kirke River, the Starcke River region and Margaret Bay (Fig. 1), met all seven FHA selection criteria (Danaher 1995). This assessment against FHA criteria was largely based on the broad-scale tidal-vegetation mapping completed through CYPLUS and a general overview of each area.

The outcomes of the Cape York NHT project include the following:

- Enhanced fisheries productivity and fishing opportunities;
- A Fisheries Resource Assessment for each of the three areas using the FHA selection criteria and assessment procedures; assessment included fish and crab surveys, identification and mapping of marine plants (mangroves, seagrass, marine succulents, etc.), and assessment of habitat-related features;
- Increased community awareness of FHAs and fisheries issues;
- Extensive consultation and negotiation with communities and key stakeholder groups in relation to the three new potential FHAs; and
- Enhanced relations between the Department and indigenous communities.

FISH HABITAT AREA CONSULTATION PROCESS

In accordance with the QFS 'FHA Selection Assessment' procedures, a candidate FHA is assessed against standard criteria, with the overall rating providing an indicator of the area's suitability for FHA declaration.

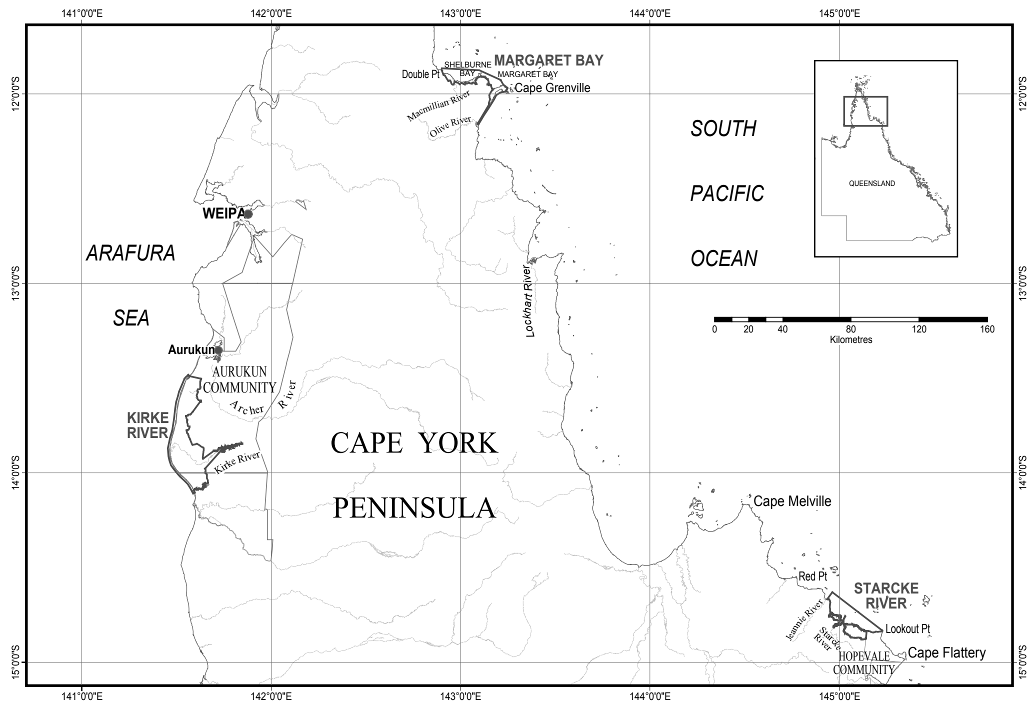

Fig. 1. Three areas for assessment and investigation as Fish Habitat Areas within the Cape York NHT project.

If the area meets the selection criteria, an extensive period of community and stakeholder consultation and negotiation is undertaken. QFS considers community and stakeholder consultation to be an essential component of developing an acceptable and effective FHA. The usual consultation process occurs over a period of 12 to 24 months, depending on the complexity of issues to be addressed, and follows a standardised, transparent process (McKinnon *et al.* 2003).

McKinnon and Sheppard (2001) state that the consultation undertaken by the QFS is intended to inform the community and stakeholders of

- the fisheries and fish-habitat values of the nominated area,
- the benefits and restrictions of FHA management, and
- the FHA management options available (A or B Management levels).

The consultation also gathers information on

- existing and planned uses within and adjacent to the area,
- the suitability and acceptability of the proposed boundary locations and Management level/s, and
- the overall level of support for the proposal.

Consultation generally involves public and individual meetings, presentations, correspondence, media releases and preparation of an Area of Interest Plan and consultation literature. At least two opportunities for community and stakeholder input are provided as part of every FHA consultation process (McKinnon and Sheppard 2001).

All FHA declarations attempt to engender community understanding of the values of fish habitats, create a sense of community ownership of their fisheries resources and provide a strong legal framework for their protection. A significant benefit of pro-active FHA declarations is that the process generates community support and interest in fisheries sustainability and fish-habitat protection well before their desire and resolve to protect this habitat is challenged by development pressure (McKinnon *et al.* in press).

CONSULTATION WITH INDIGENOUS COMMUNITIES

Although the QFS consultation procedures have been successful in delivering excellent outcomes in developed communities along the east coast, they do not take into consideration the remote location of indigenous communities, cultural diversity and understandings, and differences in communication styles between indigenous and non-indigenous people. The standard consultation procedures do, however, allow flexibility in time frames and methods of consultation. Based on this, they can be adapted to work within any community. During the first six months of the Cape York NHT project it became evident that effective communication with indigenous communities required an adaptation and departure from the 'standard' time frames, information delivery techniques and information-gathering processes as outlined previously.

The following issues outline some of the key factors taken into consideration and implemented whilst undertaking research and conducting consultation and negotiations with indigenous communities, as part of the Cape York NHT project.

ESTABLISH RELATIONSHIPS FIRST

When planning and conducting a project within an indigenous community, it is vital to establish a friendly, working relationship first. Interpersonal skills and an appreciation of the communities' custom and history are cornerstones in enabling the relationship to work (DATSIP 2000). Trust and respect must be built and experienced by all parties, before any research work, consultation and/or negotiations can begin. A trusting and respectful relationship will lead to a comfortable working environment and enable things to run smoothly and even to plan. The key to successful consultation in indigenous communities is relationship building (DATSIP 2000).

Initial contact is an important part of building a relationship that will lead to a successful consultation process (DNRM 2000). At this initial stage it is critical to identify the community leaders and elders and what activities are happening in the community. For example, when QFS officers first visited the Aurukun community to conduct research in the Kirke River, an elder's funeral service was being held. This elder was a traditional owner of the Kirke River, so any visits, research and exploration of the area by non-traditional owners had to be postponed. The local community, representative body, clan groups and elders should be contacted prior to a visit to a community and prior to the planning of any research. Preliminary meetings are not only necessary to developing relationships, but also necessary in developing and outlining the research outcomes, procedures and consultation methods.

Officers should also be aware of the cross-cultural context, understandings and differences between indigenous and non-indigenous people. Most people who conduct negotiations and consultation in aboriginal communities do not speak an aboriginal language. They also may seek scientific and/or technical information from Aboriginal people who often have limited formal education and for whom English is frequently a second language and in some cases a third or fourth one (O'Fairchaellaigh 1999). This is an important factor and needs to be taken into consideration during all stages of consultation. When a new approach is to be made to a community, establishing an open and honest relationship with community and clan leaders and elders will take time. Nevertheless, after working with indigenous communities, it is evident that this is the most useful and influential part of the process.

COMMUNITY INVOLVEMENT

For most research projects, indigenous people are often consulted and involved at the middle or end of the life of the project. This involvement is then usually in the form of providing background information, support for a project or proposal and/or permission to access traditional country. Indigenous people and communities need to be involved at all stages of a project, including planning, research and consultation. Taking the initiative to involve aboriginal people at the beginning of a project, program or the development of a policy will allow direct identification of their needs and increase the effectiveness, relevance and acceptance of any policies or services (DFYCC 1997).

Through the Cape York NHT project, QFS has involved local indigenous people, community and clan groups and rangers at all stages of the project, and in particular during the research and consultation stages. Indigenous rangers and traditional owners have been involved in carrying out research and fisheries assessments in terms of netting, crabbing, fishing and identifying habitats and vegetation. All the indigenous people involved in the Cape York NHT project were willing to learn new assessment techniques and gain an understanding of the research objectives and how these play a part in management. The Department also gained valuable knowledge about past and present use of the fisheries resources by traditional owners, and about aboriginal uses for different resources, e.g. different species of mangrove trees.

In the past, aboriginal people have felt that governments have carried out only token consultation and that this consultation has occurred merely to back up a forgone government decision (DFYCC 1997). Government officers are perceived as being representatives of a large, powerful, unfriendly and uncaring bureaucracy due to historical factors and are often viewed negatively, regardless of how friendly they may appear to be (DFYCC 1997). This is another reason why relationships, based on trust and respect, need to be established first, before any project work or consultation takes place.

Consultation and negotiation with indigenous people are critical to the success of the Cape York Peninsula NHT project. As the traditional owners of the land in question, elders, indigenous communities and clan groups form the basis of all consultation and negotiation. They are not only an integral part of consultation and negotiation, but also an essential part. FHA declaration depends on strong community and stakeholder support, and without this a FHA may not be supported and declared.

TIMEFRAMES

Most government agencies and organisations, particularly when funded by an external body, are constrained by time. Usually, these time lines require fast and efficient consultation and do not allow for relationship building and cultural constraints. Working with indigenous communities requires time, flexibility and patience. Process and time lines need to be adapted to reflect this. In most cases if these time lines are considered immediately and written into the proposal or plan, they can be adhered too.

The Department's project proposal, plan and submission were based on previous consultation with non-indigenous people, in easily accessible areas on east coast of Queensland. The proposal allowed one year for the assessment and declaration of each FHA. This included research and data collection, assessments, consultation and negotiations. The original proposal for the Kirke River area failed to take into account and allow time for relationships to be established and for the necessary planning and involvement with indigenous communities. Hence, the Cape York NHT project has gone 'over time' and will continue after the funding has finished.

In this case, the Department should have involved the relevant indigenous communities and clan groups prior to the development and submission of the project proposal. This would have facilitated friendships and relationship building and also highlighted any potential issues and complexities for each area. The project proposal might have then also built in the appropriate time lines and acknowledged potential time constraints and deviations. Time constraints in the Cape York NHT project are one of the major impedients to successful consultation, negotiation and early, agreed outcomes.

It is also critical to accept the importance of internal negotiations within clan groups. O'Fairchaellaigh (1999) says it is often tempting to delay the difficult internal negotiations given the urgent need to prepare for negotiations with the developer or government. However, unless the need to deal with this level of consultation is clearly recognised and integrated into models of project negotiations, the prospects for achieving positive agreements will be substantially reduced. This also has flow-on effects for the implementation and management of the project.

Time and timing also need to be taken into account when planning and conducting meetings and negotiation in indigenous communities. Sometimes meetings may be cancelled or deferred for cultural reasons such as a mourning period or funeral. Additionally, a meeting should also not be scheduled for a specific time, e.g. 9 a.m. or for a specific length of time. Meetings are often conducted when the community is ready to negotiate and gathers the appropriate people together. This may mean that the meeting starts at 2 p.m. instead of 9 a.m., and may extend to the following day if the need arises. People and any arrangements need to be flexible, understanding and patient. "Murri Time" is a genuine cultural practice for many Aboriginal and Torres Strait Islander people, reflecting the philosophy that being on time is not necessarily as important as it is in Western cultures. These issues need to be planned for and handled sensitively, with the aim of respecting cultural preferences (DNRM 2000).

CONTINUITY OF STAFF

Even though this is a relatively minor issue, the involvement of the same staff members for the life of the project is important to ensuring that outcomes are met and the process is achieved. As stated previously, a relationship built on trust and respect is crucial for enabling the project to run smoothly. Such relationships take time to develop and are usually dependent on the commitment of individuals involved. Project success can be severely reduced or delayed if staff members are constantly changing throughout the life of the project and the community is constantly dealing with new people. A commitment to the process by the organisation and staff for the life of the project is essential.

CONSULTATION

Although all the above issues deal with aspects of consultation, there are a number of key points in relation to conducting consultation and negotiation. Methods of consultation for FHA declaration usually involve departmental correspondence, public and stakeholder meetings and media releases.

Within indigenous communities this generic form of consultation and negotiation is not appropriate.

Consultation with indigenous communities should involve informal community visits and community meetings. This ongoing face-to-face contact also helps to build relationships, friendships and mutual respect. As stated previously, consultation arrangements need to have a flexible timetable and agenda, as arrangements can be changed completely with little or no notice due to community issues of which staff may not be aware. DFYCC (1997) says that cultural responses to time concepts are different and sometimes more value is placed on other priorities. Community meetings should provide background information and allow plenty of time for people to appreciate the details and implications. During meetings, community members may want some time alone to consider and discuss what has been said. It should be remembered that during the consultation process the outsider has a participatory role, not a controlling role (DATSIP 2000). Above all, any consultation needs to be flexible, open and honest.

KIRKE RIVER CASE STUDY

Background

The Kirke River is on western Cape York Peninsula, approximately 55 km south-south-west of the aboriginal community of Aurukun (Fig. 1). The river has a large saline lake that empties to the sea through a short lowland coastal riverine system. Extensive seasonal wetlands are associated with the river system. During the wet season (January–May) these wetlands may extend continuously from south of the Kirke River mouth to the Archer River in the north. Riparian habitats of mangroves, saltpans and terrestrial vegetation types line the riverbanks. Terrain surrounding the river is typically flat, allowing saline tidal influence to extend several kilometres upstream, especially in the dry season (Sheppard *et al.* 2001). The Kirke River and surrounding land is held as aboriginal tenure, either aboriginal Land Lease, Deed of Grant in Trust or aboriginal Reserve (CYRAG 1996). The entire river and catchment lies within lands that are managed by the Kirke River traditional owners.

Conducted in August 1999, the Fisheries Resource Assessment showed that the Kirke River met all seven FHA criteria, supported a diversity of pristine environments that have high value as fish habitats and was highly productive. With extensive mangrove and saltmarsh areas, the Kirke lake system supports a large, productive barramundi fishery. The coastal wetland communities within this river are near pristine and their associated catchments are virtually undisturbed by human development (Sheppard *et al.* 2001).

Consultation

The Kirke River was the first area chosen for investigation, assessment and possible declaration as part of the Cape York NHT project. As Fisheries staff had had very little experience in the past in terms of consulting and negotiating with indigenous communities, a consultant organisation, with staff working in the Aurukun community, was appointed to help with the project. The organisation's staff had quite extensive experience in dealing with indigenous issues in aboriginal communities in Aurukun and Cape York Peninsula. The organisation's brief was to consult and liaise with the traditional owners of the Kirke River and the community in relation to providing information on FHAs, and to discuss any issues associated with the potential declaration, the FHA Area of Interest Plan, its boundaries, exclusion and inclusion areas, and general fisheries issues.

Through the consultation and negotiations process a number of issues arose:

- Fisheries staff had to ensure that the organisation's staff members became fully aware of Fisheries legislation, FHA definition, the FHA declaration and management process and FHA issues. This education and training did not occur as quickly or early in the process as it should have and therefore several misunderstandings arose. During consultation, these were communicated to the community members and traditional owners. It was difficult to correct the misinformation and explain why it had occurred.
- Relationships between Fisheries staff and the indigenous community were not established from the start of the process, because the contracted organisation did the direct and regular consultation with the community. The lack of relationships and friendship with community members also meant there was an initial lack of trust and respect. This was highlighted to Fisheries staff during our field visit. The failure to establish the respect, trust and friendship at an early stage is considered to have undermined the FHA process.
- The Aurukun community was at the start of developing a strategic plan for the Kirke River area. Issues such as new developments, housing, water, commercial activities, etc. had not been discussed or resolved within the community, so it became difficult to simultaneously consider a new, additional management regime over the same area. The FHA consultation process also tries to acknowledge and incorporate existing and proposed developments within the final FHA proposal.

- The community felt strong antipathy towards commercial fishers working in the area. Although this fisheries-management issue is quite separate from FHA declaration, it became intertwined in the process. One misunderstanding that arose was that the community expected that a FHA would impose limits and/or prohibit commercial fishing in the area. As detailed previously, a FHA allows all forms of legal fishing.
- Continuous reporting, assessment and feedback was not firmly established and adhered to by the contracted organisation and Fisheries staff. Hence, the QFS became isolated from the ongoing FHA process and had difficulty rectifying conflict situations quickly. For example, the Department was unaware of the lack of support for the FHA proposal until staff spoke to community members and the local Council first hand.

Outcomes

Although the outcomes at this stage do not include the declaration of a FHA, the process has facilitated the learning, development and understanding of indigenous issues that can be applied in future FHA consultation. The process has confirmed the value of establishing good relationships, involving the community from the beginning of the process and timing. It has also involved and made QFS aware of other fisheries-related issues, i.e. commercial fishing and aquaculture that are important to the community.

STARCKE RIVER REGION CASE STUDY

Background

The Starcke River Region lies on the east coast of Cape York Peninsula, and stretches north from Lookout Point to Red Point (Fig. 1). This area contains a number of creeks, tributaries and two main rivers, the Starcke River and Jeannie River. The coastline between Cape Flattery and Cape Melville has been described as one of the most diverse on Cape York Peninsula. It includes large mangrove areas, fringing coral reefs, melaleuca forests, freshwater wetlands, tidal flood plains, sand dunes and rocky headlands (Kalis 1993). The nearest urban area is Hopevale, approximately 60 km south of the Starcke River. Cooktown is 45 km south of Hopevale.

The coastal wetland vegetation communities of the Starcke River area represent a diversity of environments that have value as both fisheries and dugong habitats, including sheltered bays, shallow and deep-water seagrass meadows, coral reefs, exposed coastlines with mudflats, sandflats and saltmarshes, and numerous mangrove community types. Although their economic value has not been estimated, these wetland habitats contribute significantly to the local fisheries by the food, shelter, breeding and nursery grounds that they supply. The contributions of the recreational and cultural values to the area are also key considerations (Sheppard *et al.* 2001).

The data, assessments and analyses have shown that the Starcke River Region meets all seven FHA criteria, supports a diversity of pristine environments that have high value as fish habitat, and is highly productive. The coastal wetland communities within this region are near pristine and their associated catchments are virtually undisturbed by human development (Sheppard *et al.* 2001).

Consultation

Consultation with the Cook Shire Council, Hopevale Aboriginal Council, Hopevale Community, traditional owners and the Ngulun Land Trust began in 1999. This was prior to the planning and timing of the fieldwork and any negotiation about FHAs and boundaries. The initial consultation period was made up of many informal meetings to establish relationships, trust and respect. The Hopevale community has been exposed to many government officers and bureaucrats in the past. Usually, these government officers visited the community for several hours or a day to inform the community about a certain project or to gain permission to access their country, and had never returned. For this reason, the relationship-building part of the FHA process became even more important.

Although members of the team and project changed over time, the project leader and Fisheries indigenous liaison officer remained throughout the life of the project. At all stages of the process, the community, elders, and traditional owners could contact and relate to these two people. This continuity was vital for the success of the project.

Two local indigenous rangers were involved in planning and conducting the field surveys for the fisheries resource assessment. The fieldwork involved three weeks in the field, camping near the Starcke River and Jeannie River. The indigenous rangers were involved in all aspects of the fieldwork – from netting and crabbing to identification of mangroves and other fish habitats.

The next stage of the process was to prepare an 'Area of Interest Plan' for the proposed Starcke River FHA. The proposed boundaries of the FHA were established by talking to the Ngulun Land Trust and liasing with the Hopevale Aboriginal Council and Cook Shire Council. Based on the data collected and these negotiations, the Area of Interest Plan that was prepared as a result encompassed vast areas of mangrove and seagrass beds all within and adjacent to the Ngulun Land Trusts country. The Ngulun Land Trust has freehold tenure over most of the Starcke River area, so it was essential to make sure the proposed FHA boundaries reflected their aspirations and needs. Thereafter the consultation process involved more informal and formal meetings with the Ngulun Land Trust as well as other community members, clan groups, councils and stakeholders. This part of the process involved an information gathering and exchange by all parties. This was to ensure that all stakeholders and the community understood and supported the rationale, potential benefits and management implications of a declared FHA. As stated previously, community and stakeholder support is imperative to the whole FHA process. The successful declaration of FHA hinges on this support.

Outcomes

The ongoing relationships formed with members of the indigenous community and clan groups are one of the main achievements of the Cape York NHT project. The relationships are a product of the staff commitment to the process and project and the willingness and understanding of the indigenous community. Although the process has not been perfect, it has far exceeded any consultation and negotiation completed in the past. Flexibility, patience and the involvement of the indigenous community have meant that the issues associated with the declaration of a FHA for the Starcke River are understood and project outcomes have been met. This has also paved the way for ongoing and future relationships, interaction and a joint management approach for the fish habitats of the area for the benefit of future generations.

MARGARET BAY CASE STUDY

Background

The Margaret Bay or Wuthathi region lies on the east coast of Cape York Peninsula, and stretches north from the Olive River in the south to Double (Etatapuma) Point in the north (Fig. 1). This area contains a number of creeks, tributaries and two main rivers, the Macmillian River and the Harmer Creek. Large intertidal flats stretch across the bay and extensive areas of silica sands and perched dune lakes lie inland of the area.

The Margaret Bay region has been described as an area of conservation significance and high wilderness value (Schneiders 1999). The bay is sheltered from the prevailing south-easterly winds and supports extensive seagrass beds, which vary from dense to sparse (Danaher 1995). The region was proposed as an initial priority area for government support for management actions and protection of natural resources (CYRAG 1996). The nearest urban area is Portland Roads, just north of Lockhart River, which is approximately 100 km south of Shelburne Bay. The Fisheries Resource Assessment in 2001 showed the Margaret Bay region to comprise a diverse range of habitats: shallow sand flats, complex mangrove communities along river and creek banks, islands and reefs, extensive seagrass beds, large areas of saltpans, freshwater wetlands and perched dune lakes. The tidal waterways constitute a productive fisheries area, particular for inshore fishes. The assessment concluded that the Margaret Bay region met all FHA criteria, supports a diversity of pristine environments that have a high value of fisheries habitat, and is highly productive (Sheppard *et al.* 2002).

Consultation

As in the Starcke River region, consultation with the local council, traditional owners and stakeholders began early in the process. Informal discussions began in 2000, prior to any planning, fieldwork and/or negotiation about FHAs and boundaries. The initial consultation period was made up of many informal meetings to establish relationship, trust and respect. In contrast to the other two case studies, however, the traditional owners of the Margaret Bay area, the Wuthathi people, do not live within a sole community or locality. Traditional owners, elders and members of the Wuthathi Land Clan live in Cairns, Lockhart River, Portland Roads and Kalpower. Owing to these constraints, the majority of the consultation to date has been with the Chair of the Wuthathi Land Clan and members in the Cairns area. This consultation has included mostly informal meetings and face-to-face consultation. To date, the dissemination, gathering and understanding of information has gone well, and issues related to the area have been discussed. Modifications have been made to the Area of Interest Plan, to reflect the needs, aspirations and wants of the traditional owners. In the Margaret Bay region, however, these modifications have resulted in an increase in the size and area of the proposed FHA. Perhaps because the traditional owners do not occupy the lands, the potential for development is limited. The Wuthathi people also have great spiritual connection to the lands, water and islands in the Margaret and Shelburne Bay region. Their need to protect this cultural significance and diversity is intrinsically linked with the need to protect the important marine and terrestrial habitats. As with many aboriginal people, the connection between the land, sea and spirits is strong.

Outcomes

The proposed FHA in the Margaret Bay region still requires considerable discussion, consultation and negotiation with the Wuthathi Land Clan and other stakeholders. To date, the communication has highlighted the important linkages between the land and sea and, in the Margaret Bay area, between the sand dunes and perched lakes, and the estuarine systems, marine bays and islands. Further consultation will help to further disseminate information and facilitate discussion on the proposed FHA.

DISCUSSION

The Cape York NHT project case studies show various ways of conducting research, consultation and negotiation within different indigenous communities, each with different results. Overall, what worked best was interactive planning, full community involvement at all stages of the project and allowing time to build relationships, trust and respect. Consideration of these issues early in the process can facilitate a friendly, flexible and enthusiastic environment for consultation and negotiation.

Through the Cape York NHT project, better results have been achieved with more experience and refining of the FHA declaration process. This education has led to the need to develop and implement separate guidelines for indigenous consultation. These guidelines should be developed with aboriginal people and can facilitate Fisheries staff in organising, planning, implementing and consulting within indigenous communities in the future.

There are also other options for joint management that should be considered. These may include local management committees with QFS membership and the implementation of indigenous liaison officers. QFS has liaison officers who work throughout Cape York Peninsula. These officers have established friendly working relationships with indigenous people to encourage and foster community growth and development. For example, one of these liaison officers was involved throughout the Starcke River process, which has proven to be invaluable. His support and interaction with the traditional owners, Ngulun Land Trust, council and community members were regular, friendly and formed the basis of the relationship between QFS and the community. As the process has focussed on building relationships within the community, it is essential to continue this contact, communication and presence in the areas. Ongoing extension is required in order to maintain awareness and to report on problems or potential management issues; this will foster the relationships previously established and continue fisheries involvement and support in indigenous communities.

Other options for joint management should include the development of specific management plans for each proposed or declared FHA. This issue has been raised by indigenous communities, on the basis of the wide range of fisheries and fisheries management issues experienced. For example, in the Starcke River area, a FHA management plan would also integrate the dugong- and turtle-hunting management plan.

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SUCCESS FACTORS IN MANAGEMENT OF THE GREAT AUSTRALIAN BIGHT MARINE PARK (SOUTH AUSTRALIAN AND FEDERAL AUSTRALIAN WATERS)

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Abstract

The location and extent of the marine park are presented as well as the values, highlighting marine mammals, benthic life and sediments, and multiple use. South Australian waters of the marine park were declared in 1995 and 1996, and adjoining Australian federal waters were declared in 1998. Both State and federal sectors are managed as one park and there are four zones including a no-take no-entry sanctuary and seasonally closed zones. Management strategies include joint State and federal administration, and cooperative arrangements in regard to community and industry participation, performance assessment, interpretation, and compliance and enforcement. Tourism, especially enterprises run by indigenous organisations, are a newly developing economy in the region and fit in well with the management of the marine park. The Great Australian Bight Marine Park complements tourism, industry and natural resource management in the region.

Keywords: benthic, bight, mammal, marine, Yalata

INTRODUCTION

This paper provides an overview of the location and establishment of the Great Australian Bight Marine Park (GABMP) and a brief outline of the significant natural values of the region. Success factors are presented in regard to management initiatives, and the focus is on community and stakeholder involvement in strategic planning as well as taking part in park management programs.

The Great Australian Bight (GAB) extends over 1200 km, from Cape Pasley (near Esperance) in Western Australia (WA) to Cape Catastrophe, at the entrance of Spencer Gulf in South Australia (SA) (ACIUCN 1986). The SA and Australian federal governments established adjoining marine parks in the GAB between 1995 and 1998, to protect the region's outstanding marine biodiversity. The combined park covers an area of approximately 2.15 million hectares and is managed as a single marine park under a cooperative arrangement between federal and State government agencies.

The Park contributes to the National Representative System of Marine Protected areas and covers approximately 12% of the Eucla bioregion; a significant portion of the park extends outside the Australian bioregion classification system. Included under category VI of the IUCN guidelines for Protected Area Management Categories, the Park is managed for the protection of biological diversity and provides for sustainable use of natural resources.

There are some factors about the Park that make it quite different from most marine protected areas (MPAs). It is in a very remote area and there is virtually no access to the ocean from the land adjoining the park; most of the coast is an unbroken cliff face for nearly 200 km, and the remaining 100 km or more is beach exposed to high waves and strong currents. Fishers using fast lobster boats take a minimum of 12 h to reach the Head of Bight from Ceduna, the closest port. Much of the Park takes in a broad, shallow, mostly sandy shelf, and around 200 km south from the Head of Bight the seabed is only 200 m below the surface. However, from there to the limit of the Park, another 280 km south, the depth plunges to around 5 km. The Leeuwin Current flows south and east around the tip of WA and swirls along the Bight bringing warmer, less saline, waters as well as a variety of tropical species, including the commercially valuable southern bluefin tuna.

The Head of Bight is the most significant calving area for the southern right whale, *Eubalaena australis,* on the Australian coast, and the high cliffs overlooking this area provide spectacular views of the whales. Viewing facilities here, and beach camping areas to the east, are becoming an important enterprise for the Yalata people who have a lease over land adjoining the Marine Park. Australian sea lions (*Neophoca cinerea*) and little penguin (*Eudyptula minor)* are residents at the base of the Bunda Cliffs, which have protected these populations from various threats and also make it difficult to increase our knowledge about them.

As well as protecting the unique biodiversity of the Bight, there are three main focus areas set out in the plans of management for the Park: marine mammals, the benthic environment and the sustainable use of natural resources.

MARINE MAMMALS

Around 20 cetacean species have been recorded in the GAB. The 'Head of Bight', the northern-most part of the coastline, is a very significant calving and breeding area for the endangered southern right whale. Australian sea lions and bottlenose dolphins, *Tursiops truncates,* are residents in the area, and New Zealand fur seals, *Arctocephalus fosteri*, are being noted more frequently.

The huge southern right whales (to 17 m and 80 tonnes) visit the south coast of Australia each year to calve and to mate, although individual cows give birth on a three-year cycle. The whales start arriving in the coastal waters from mid May each year and usually depart by mid October. Calving females remain in the area for around 70 days and others for around 20 days (Pirzi and Burnell 2000). They are not known to feed during this time. An aerial survey in 2001 by John Bannister of the WA Museum provides a population estimate of between 1200 and 1300 whales between Cape Leeuwin in WA to Ceduna in SA; that survey recorded 77 adults and 46 calves in the marine Park.

Around 80% of the 10,000 to 12,000 total population of Australian sea lions reside along the coast of SA. A small but important part of this population occurs in the GABMP. Ten small breeding colonies at the base of the Bunda Cliffs were only discovered in 1994 (Dennis 2001) and only three pupping surveys have occurred, with an average of 60 pups having been recorded each survey from an average total population of around 200. These sea lions have a breeding cycle of 17–18 months, and the timing can vary between regions. Complicating monitoring further in the marine park is the difficulty in counting the sea lions at the base of the cliffs, since they are often in caves, under ledges, in crevices between boulders and in thick vegetation, and the cliff edge is extremely fragile and is dangerous to approach.

BENTHIC LIFE AND SEDIMENTS

There is a high level of biodiversity in the Bight, especially in regard to benthic species; between 75% and 90% of species of fish, molluscs, echinoderms, and red algae are found only in the GAB. This high level of endemism seems to be the reverse on the tropical north coast of Australia, with between 10% and 15% of those species being endemic. Owing to the arid climate and resulting minimal run-off of sediments from the surrounding land, the marine sediments are primarily calcareous, with bryozoans, foraminifers, and molluscs being important contributors. These 'pristine' sediments are valuable for the study of past climate change and of other ocean parameters.

NATURAL RESOURCES

Fishing activity that affects the benthic environment is prohibited and the GAB trawl fishery operates in waters outside the Park. This fishery primarily targets deepwater flathead, *Neoplatycephalus conatus,* and bight redfish, *Centroberyx gerrardi,* in the 100–200 m contour and orange roughy and dory species in deeper water. Other fisheries, such as shark, marine scale, and lobster fisheries, operate under permit conditions in federal waters and under Fisheries licences in State waters. The Park is zoned for various activities from total prohibition of access, entry and fishing methods, to seasonal entry and harvesting. The shark fishery is the most significant in the Park and the main sharks targeted are the school shark, *Galeorhinus galeus*, gummy shark, *Mustelus antarcticus,* and bronze whaler, *Carcharinus brachyurus.* Other commercial fish species include mulloway, *Argyrosomus hololepidotus* Australian salmon, *Arripis esper* leatherjackets(family Monacanthidae) and trevalla (family Centrolophidae). Southern bluefin tuna *Thunnus maccoyii* and pilchards are generally caught to the east of the Park. Lobsters, *Jasus edwardsii,* are taken in the park to the east of the Head of Bight.

Recreational fishing by hand line and rod is allowed from the beaches at the east and west portions of the Park. Petroleum exploration occurred in the Bight region in 2001 and covered part of the southernmost zone of the park (Benthic Protection Zone). It is not known at this stage whether any areas were located with potential for commercial extraction.

Tourism is a growing use of the natural resources in the marine park, with travellers using the lookouts off the Eyre Highway, overlooking the Park. Several vehicle tour operators visit the area and a scenic tour / whale-watching aircraft operates from the Nullarbor Roadhouse. The Yalata Aboriginal community leases land adjacent to the Marine Park and have developed a significant tourist enterprise based on whale watching, bush camping and recreational fishing.

MARINE PARK ZONES

The park is zoned for various levels of protection and use:

- **Sanctuary Zone** (State waters) – permanently closed to all boating and commercial fishing, this zone takes in the main calving area for the southern right whale and Australian sea lion pupping and haul-out sites;
- **Conservation Zone** (State waters) – closed for six months of the year (1 May to 31 October); this closure coincides with the annual migration of southern right whales to the GAB and extends the protection provided by the Sanctuary Zone;
- **Marine Mammal Protection Zone** (federal waters) – closed for six months of the year (1 May to 31 October); and
- **Benthic Protection Zone** (federal waters) – fishing can take place throughout the year under permit; however, no activity can take place that may affect the benthic environment, e.g. benthic trawling is prohibited.

SUCCESS FACTORS

Success factors in the management of the GABMP include

- Cooperation among management agencies
- Community and industry participation
- Performance assessment
- Interpretation
- Compliance and enforcement

Cooperation among management agencies

The relevant federal and SA management agencies have established cooperative strategies to manage both federal and State waters of the GABMP as one Park. The basis of this cooperation is the establishment of a Steering Committee representing the management agencies, which are:

- Marine and Water Division of Environment Australia,
- National Parks and Wildlife of the Department for Environment and Heritage SA,
- Fisheries Division of the Department of Primary Industries and Resources SA
- Tourism Development of SA Tourism Commission

The committee members are senior executives who have the authority to establish an Annual Business Agreement between the agencies, outlining management strategies and allocation of funds. These formal arrangements are developed at two meetings each year. Progress is monitored, and issues are addressed as required, in out-of-session communication with the park manager and among committee members throughout the year. The committee takes advice from a non-government Consultative Committee (the role of the Consultative Committee is outlined below, under 'Community and Industry Involvement'. The federal government and SA signed a service-level agreement for management of adjoining MPAs in 2002, and this agreement generally follows the cooperative management arrangements outlined in the Annual Business Agreements for the marine park.

Community and industry involvement

A primary focus for the Great Australian Bight Marine Park Steering Committee is to have representation, involvement and cooperation of all stakeholders in managing the Marine Park.

The fishing industry has been pro-active in park management, and a Consultative Committee has been established to advise management from the perspective of the community and industry. Yalata Land Management at the Head of Bight are actively involved in management programs, and researchers and tour operators assist when they are in the park area.

Fisheries project - The Fisheries Project was a fishing industry initiative in 2000 to become involved in management and monitoring programs for the Park. The project was funded by a FarmbBis grant and involved the cooperation of the South Australian Research and Development Institute (SARDI), National Parks and Wildlife SA (NPWSA), and the SA Museum to provide technical support and training. Fishers were trained to collect relevant information, such as operating an underwater video camera and recording information about catch, by-catch and discarded species. Several lobster fishers in the region record catch information on a voluntary basis and this will also be used in the development of a sustainable-use strategy for the Park. NPWSA and the SA Museum produced a marine-mammal identification kit for fishers to record sightings, and these kits were distributed to fishers in the lobster fishery. Temperature loggers were purchased and deployed by a lobster fisher in a north–south transect to the east of the Marine Park. These loggers were retrieved in 2001 and the data will be included in studies being conducted by SARDI in the GAB region including the Park. SA Maritime Museum was commissioned to conduct a study of the maritime history of the GAB and this information will be used in interpretation programs for the Park. The momentum of the Fisheries Project did not progress beyond the initial stage until the Consultative Committee was formed and a sustainable-use performance assessment strategy developed to provide guidelines for further involvement by the fishing industry.

Consultative Committee - A Consultative Committee was formed in 2001 from representatives of non-government stakeholders in the GAB region.

The Committee is structured to achieve a suitable representation of stakeholders in the region and to have an effective balance of appropriate knowledge and experience; the make-up of the 12-member committee is

- Aboriginal groups associated with land adjoining the marine park (3 members) and a representative from the Aboriginal Legal Rights Movement (1 member)
- Marine research from Flinders University in Port Lincoln (1 member)
- Community Conservation Groups (2 members)
- Federal and State fishing industries (2 members)
- Strategic environmental planning (1 member)
- Tourism and recreational fishing (1 member)
- Local government (1 member)

The main responsibility of this committee is to provide advice to the Steering Committee from community and industry perspectives. The Committee has input into strategic planning as well as assessing the performance of the management prescriptions for the marine park, identifying performance indicators, and proposing monitoring programs. Working groups from the committee will be allocated to work with the park manager to address the various issues from committee meetings, and committee will present recommendations to the Steering Committee.

Yalata land management - The Yalata Indigenous Protected Area is managed by the Yalata Land Management (YLM) rangers. The coastline of Yalata land adjoins the Park, and the Head of Bight and other coastal areas of Yalata land are significant areas in relation to a cooperative management agreement with the Park. Under the agreement, the Park partly funds the salary of the YLM supervisor and in turn the supervisor is responsible for making sure all aspects of the agreement are addressed and reported on. The agreement covers

Visitor management - Providing information to visitors including distributing brochures and erecting signs, providing recreational fishing regulations, and providing park management with visitor statistics and comments from the visitors' book.

Surveillance - Making observations of the Park from the coast, especially from the high cliffs. The position of any vessel is plotted by triangulation and this is forwarded to the Park manager. YLM rangers take part in aerial patrols to photograph vessels and record other relevant information requested by the park manager.

Collection of potentially entangling debris - Nets, ropes and other potentially entangling debris are collected from the beaches and samples are sent to the park manager to establish a database and to determine the origins of the debris.

Assist with research operations- Assistance is provided to research operations especially in making daily counts of the southern right whales. These counts are recorded on the same data sheets as the research that has been happening at the Head of Bight since 1991. Of particular importance to researchers are the records taken when the researchers are not in the area, especially when the first whales are arriving and the last ones depart the area.

Assistance with cliff rescue operations - The rangers have been trained in basic rope skills and this training is continuing so that they can assist in the event of any cliff rescue operation. They will be able to provide important people management and first aid if necessary.

Four Yalata rangers have also recently been authorised as Wardens under the *National Parks and Wildlife Act 1972* (SA) and have significant powers to administer environment legislation on Yalata land. The YLM supervisor is a member of the GABMP Consultative Committee.

Other stakeholders - Agreements and informal arrangements with other stakeholders operating in the Park locality are an effective way of increasing surveillance, making general observations and assisting with management activities.

The Park has an agreement with Whale Air, an air tour operator working out of Nullarbor Roadhouse taking tourists for short flights around the Head of Bight area. The pilot records the arrival of the first whales in the area in May and the departure of the last in October. Records are taken of the number of whales in the area and the number of calves born, and any unusual sightings. These tours are running for most of the year although there are many more flights during the winter months, which is the time the southern right whales are in the area. The pilot will record the location and activity of vessels in prohibited areas of the Park and relay this information to the park manager.

Two land-tour operators regularly use the area and both will report any unauthorised activity or unusual events. One of the operators represents tourism and recreational fishing on the Consultative Committee for the Park. The Far West Coast Professional Fisherman's Association support the Park and are consulted about management actions and provide information about fishing activity in the region.

Performance assessment

Working cooperatively and developing partnerships with relevant agencies and with industry and the community will ensure that effective performance assessment is achieved and maintained.

SARDI was contracted to gather resource information for the preparation of the management plan for the GABMP; this was done in 1995 and 1996. Part B of the plan contains information about the resources in the area and provides a basis for the development of performance assessment strategies. This work was funded by a grant from the (federal) Commonwealth Ocean Rescue 2000 program.

Environment Australia held a GAB scientific workshop on Kangaroo Island, SA, in 1998. Participants represented relevant research organisations, non-government stakeholders, industry, consultants and government agencies. The purpose of the three-day workshop was to identify existing research programs and develop management objectives for the marine park to assist with the planning process. This workshop followed a joint Australia/USA workshop on ocean dynamics in the GAB hosted by Flinders University in Port Lincoln in September–October 1998. Both workshops provide a comprehensive account of research and monitoring in the region and the proceedings also make a valuable contribution to the development of performance assessment strategies for the Park.

Whale research consultant Steven Burnell has been monitoring southern right whales at the Head of Bight since 1991, resulting in an extensive database on the populations visiting there each year, including the number of calves born. Burnell has also built a photo-identification database of individual whales for studies of life history and movement. Since 1993, John Bannister of the WA Museum has conducted annual aerial surveys of southern right whales along the south coast of WA and extending to Ceduna in SA at the peak of the calving season in August–September. This survey includes the entire coastline of the Park. Information from both research programs is valuable to the Park. Aerial surveillance of the entire park coastline, and intensive monitoring from the cliffs, provide an opportunity to record a range of observations in regard to the marine environment.

The Fisheries Project mentioned previously has demonstrated that the fishing industry in the GAB has the ability and commitment to participate in management of MPAs, especially in the assessment of the performance of management prescriptions. This involvement will continue as part of the sustainable-use performance-assessment strategy for the Park.

Research grants were awarded to SARDI for the development of performance-assessment strategies, two grants in relation to the benthic environment and one relating to sustainable use. Review of relevant literature on the benthic environment will

- identify existing data sets and research programs;
- synthesise these data;
- determine the nature and status of ecological communities; and
- identify additional data required.

Work related to the design of a benthic monitoring program will

- use information from the literature review;
- conduct relevant field trials;
- establish sampling sites in the Park;
- establish control sites outside the Park;
- collect physical, chemical and biological data/samples;
- select indicator species and parameters; and
- develop a performance-assessment strategy including rapid assessment techniques.

The SARDI research vessel *Ngerin* will be in the region conducting other studies and this will greatly reduce the cost of conducting vessel-based research in the Park.

The sustainable-use project will be a review of available fisheries information to

- describe the patterns of fishing activities;
- determine how existing data can be used to monitor sustainable use;
- identify any additional requirements for monitoring;
- assess any requirement for observer coverage of fishing activities;

- select suitable indicators of harvested catch and by-catch, and discarded species; and
- link this project to the Benthic Protection Performance Assessment Strategy.

The work of several other agencies and industries will assist SARDI to develop performance strategies for the park. Most of the recent work was done by CSIRO from survey vessels, which included AGSO and Adelaide University projects. Lincoln University has conducted considerable work in the GAB and has a marine research facility in the region at Port Lincoln. Woodside Petroleum has recently completed seismic exploration work, which covered parts of the Benthic Protection Zone of the Park. Permit conditions provided for a marine-mammal observation program, and a bird survey was conducted at the same time. This information can be obtained only in conjunction with another project, otherwise the cost would be too great.

The Consultative Committee for the Park will play an important role in providing advice to management about performance assessment.

Interpretation

The management agencies have combined their resources to provide interpretive material for the Park on the development of web sites, production of brochures and signs, and various media releases. There are both South Australian and federal web pages for the park and these are linked to the home pages of the respective agencies. Brochures have been prepared, edited and printed cooperatively and distributed widely in the region. The State and federal fisheries agencies have distributed brochures and other management information to licence holders operating in the Bight.

YLM is installing interpretive signs at ten locations on the land adjoining the park, most of these being on parks either side of Yalata land. The YLM facility at the Head of Bight is focal point for visitors, and rangers at the entry station hand out interpretive material provided by the Park. Valuable information on visitor numbers and comments from the visitors' book are provided to the Park as part of the cooperative agreement.

Compliance and enforcement

The first portion of the Park was established under SA Fisheries legislation, and Fisheries officers are responsible for managing fishing activity in State waters. Six SA officers (NPWSA and Fisheries) were trained and authorised in 2001 to administer the federal *Environment Protection and Biodiversity Conservation Act 1999*, giving State officers the ability to manage compliance in both State and federal waters of the park. NPWSA and Fisheries officers conduct risk assessment of fishing operations in the region and collaborate to develop annual compliance and enforcement action plans.

In October 2001, Customs conducted a sea patrol in the Park and with NPWSA officers boarded two vessels conducting unauthorised fishing operations in the Marine Mammal Protection Zone of the Park. Coastwatch have flown over the park on several occasions in transit between Adelaide and Esperance in WA, and procedures are in place to identify, position, photograph and report any vessels seen in the Park region.

Police officers in the region have taken part in joint surveillance patrols with NPWSA, Fisheries and YLM. Police and Fisheries officers have assisted in training Yalata wardens. Starling control officers from Western Australia have agreed to report any vessels seen during their patrols along the cliffs from the WA border to the Head of Bight.

The agreement between YLM and the park has been outlined under 'Community and Industry Involvement' and the emphasis here is on the surveillance activity undertaken by them. During the winter months YLM officers record daily counts of the whales from the cliff-tops and this provides a good view of the eastern portion of the Park out to the southern boundary of the Marine Mammal Protection Zone in federal waters. In the summer, further observations are made during patrols to the beach camps to the east of the Head of Bight. Night patrols are conducted at selected times as a result of risk-assessment exercises. Vessels are positioned by compass triangulation from points along the cliffs and if further information is required the air-tour operator from nearby Nullarbor Roadhouse will take an accurate position as well as record any activity. With these two agreements the surveillance of the eastern portion of the Park is comprehensive and the only problem is identifying vessels at night.

Fishers of the West Coast Professional Fisherman's Association and the Northern Zone Rock Lobster Fishery support the Park and were involved in the original Fisheries Project. Some individuals supply information to management in relation to critical periods with potential for unauthorised activity.

SUMMARY AND CONCLUSION

The GABMP has developed effective arrangements for the development of partnerships for cooperative management. These partnerships are relatively recent and will develop and evolve over time, and we shall continue to improve them. However, it is time now to further expand our network to become more aware of and involved with national and international biodiversity management, to facilitate the exchange of ideas and successful management actions. The World Aquatic Protected Areas Congress 2002 provided an effective and timely opportunity to do this.

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RESTORATION OF KOARO (*GALAXIAS BREVIPINNIS*) IN A NEW ZEALAND LAKE – INTEGRATING TRADITIONAL INDIGENOUS RESOURCE MANAGEMENT PRACTICES WITH CONTEMPORARY CONSERVATION BIOLOGY

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Abstract

A collaborative project between the Department of Conservation (DOC) and Māori to explore options for restoration of a traditional native fishery in a central North Island lake provides a case study for conservation project design that integrates traditional natural resource management practices of an indigenous people with contemporary western science.

The establishment of a world-renowned rainbow trout fishery in the Rotorua lakes in the 1880s resulted in the demise of an existing native fishery. This fishery strongly contributed to the cultural identity of central North Island Māori, and was an integral element of the natural character of the lakes. A key outcome of the Treaty of Waitangi claims settlement process in New Zealand is the building of partnerships between iwi Māori and Crown agencies. The opportunity for collaboration to restore a lacustrine ecosystem has its genesis in the aspirations of local Māori to re-establish their native fishery by engaging the DOC's interest in maintaining populations of native freshwater species within their natural range. Development of a project goal and selection of an appropriate lake for the project is no easy task. The goal must provide for a level of traditional harvest while restoring viable populations. In addition, the project must anticipate the social conflict that will be generated by the need to remove trout from the chosen lake. A Project Framework, structured in accordance with partnership principles, evaluates options and guides implementation in phases with restoration targets defined within spatial and temporal boundaries according to ecological feasibility and social acceptability.

***Keywords*:** Koaro, restoration, traditional practice, partnership, lacustrine

INTRODUCTION

A complex of 17 freshwater lakes in the Rotorua District in the central North Island of New Zealand constitutes the Te Arawa Lakes group, known more commonly as the Rotorua Lakes (Fig. 1). A collaborative project between the Department of Conservation (DOC) and Te Arawa[1] to restore a traditional native fishery in a lake or lakes within this group presents a complex challenge for conservation project design. The project aims to integrate the traditional natural resource management practices of an indigenous people with a contemporary scientific approach to biodiversity restoration, within a socio-political context where there is significant potential for adverse reaction from some sectors of the community.

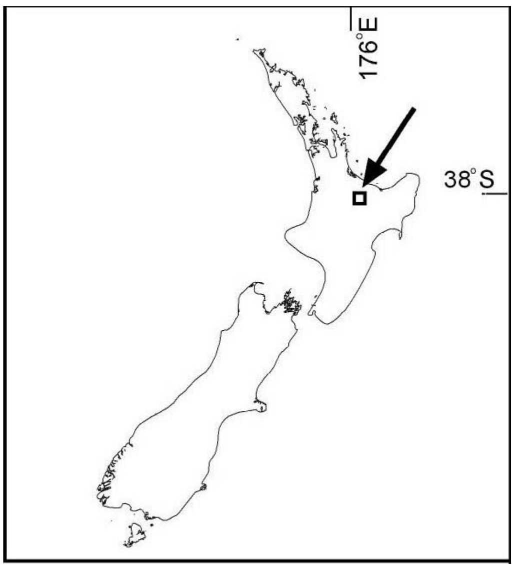

Fig. 1. Location of Te Arawa Lakes on North Island, New Zealand.

[1] Te Arawa is the federation of tribes now resident in the Rotorua district that traces its origins to the arrival of the Arawa canoe at Maketu on the central Bay of Plenty coast.

The establishment of a world-renowned fishery for rainbow trout (*Oncorhynchus mykiss*) and to a lesser extent for brown trout (*Salmo trutta*) in the volcanically formed Te Arawa Lakes complex in the 1880s resulted in dramatic changes to lacustrine ecosystems (McDowall 1990a, 1990b; Rowe 1990; Allibone and McIntosh 1999). Trout, together with their introduced forage food common smelt (*Retropinna retropinna*), severely altered food -web interactions in the lakes and reduced the abundance of the native fishery through both direct predation and competition for food and habitat (McDowall 1990a, 1990b;Young 2002).

The native fish component of the original ecosystems provided a fishery that strongly contributed to the cultural identity and practices of Te Arawa as an inland freshwater lakes people (Walker 2001) and was an integral part of the natural character of the lakes. Koura (*Paranephrops planifrons*) and kākahi[2] (*Hyridella menziesi* (Hyriidae)) are elements of the traditional fishery that remain in moderate numbers and that are still occasionally harvested. The native koaro[2] was historically a major food resource in its juvenile form ('whitebait') (Buck 1921; Phillips 1924; Best 1929; Armstrong 1935; Phillips 1924), but declined dramatically as the main forage food for trout in the early years after their liberation (McDowall 1990b; Strickland 1993). It occurs today only as small remnant populations (Young 2002) that do not provide any level of sustainable harvest.

Te Arawa are seeking redress for a range of historical grievances relating to the lakes through the Treaty of Waitangi claims process[3], their claim being known as the 'Te Arawa Lakes Claim'. Loss of the traditional native fishery is one aspect of the claim. The New Zealand Biodiversity Strategy commits DOC to maintaining or restoring viable populations of native freshwater species within their natural range. Section 4 of the *Conservation Act 1987* also obliges DOC to give effect to the principles of the Treaty of Waitangi. Both Te Arawa and DOC thus clearly have a mutual interest in the opportunities afforded by this collaborative project.

The significant degradation of Te Arawa's traditional fishery means that many of the traditional practices historically associated with it (Buck 1921) have not been widely practised in recent times. This has inevitably been accompanied by loss of the traditional knowledge upon which they were based. Much specific vocabulary has been lost from contemporary Māori language usage, place names that were based on aspects of the fishery have disappeared or knowledge of their significance has been lost, and so on. Te Arawa are keen to see a revival of the fishery and to reassert a major role in its management.

Indigenous knowledge of the substantial nature of the fishery, developed during pre-European times, provided a framework that assisted sustainable management using traditional practices such as *rāhui*, a temporary prohibition on harvest of a resource to allow time for its natural replenishment. These practices operated in the absence of the sort of major disturbances that subsequently occurred with European settlement. Today, the fishery exists only in severely degraded remnant form and is subject to ongoing competition and predation pressures from introduced trout and common smelt. Even if indigenous knowledge were still intact, it alone would be inadequate to restore the fishery; an in-depth understanding at an ecosystem scale of predator–prey interactions, the population dynamics of desirable species, and appropriate management practices is required.

The application of management techniques for desirable and undesirable species to achieve an ecosystem-focused restoration goal at a particular location is often referred to as 'integrated management'. In New Zealand, an integrated management approach has provided the ability to manage parcels of land with high conservation value as entities separate from their surrounding landscapes. Such parcels of land are referred to as 'mainland islands'. External pressures on these units are minimized and desirable biodiversity attributes are managed and restored at an ecosystem scale.

Mainland islands management has become a key biodiversity conservation tool in New Zealand. DOC currently manages 6 formal and more than 20 informal mainland islands. To date, however, all mainland island projects are focused on terrestrial ecosystems. This project, which requires an integrated management approach to restore an indigenous fishery at an ecosystem scale, is the first exploration of the mainland island approach for a freshwater aquatic ecosystem. With this project, DOC stands to gain considerable conservation management experience and an enhanced ability to maintain New Zealand's unique aquatic biodiversity.

This project, then, is a collaboration between Te Arawa and DOC to promote understanding and

[2] Koura is a freshwater crayfish, kākahi a freshwater mussel, and koaro is a galaxiid species that was historically abundant in the Te Arawa lakes.

[3] Grievances for breaches of the Treaty of Waitangi, signed between the British Crown and Maori in 1840, are currently being addressed through the lodging of claims with the Waitangi Tribunal.

synergies between their respective knowledge systems, and to explore how these can be applied together in contemporary restoration and management of an indigenous freshwater fishery.

The project goal and objectives are strongly focused on cultural aspirations. The administrative framework around the project manifests a strongly cultural dimension. Te Arawa chair the Steering Committee and meetings are run in accordance with traditional Te Arawa *kawa*[4]. The project aims to build capacity within the tribe so that the iwi[5] will eventually assume full responsibility for it. At the same time, the project unashamedly uses the pragmatic approaches offered by contemporary concepts of ecology, conservation science and management, and sustainable use, to achieve its objectives. Reports and report-writing are part of the communication apparatus of science; the following discussion largely represents the science perspective of the project, and cannot be expected to adequately reflect the cultural framework around it, or the partnership between traditional indigenous knowledge and aspirations and contemporary science that it represents.

Project goal and objectives

A project goal was developed by the Steering Committee. This emphasises ongoing relationship-building between Te Arawa and the DOC.

Draft project goal

A working partnership between Te Arawa and the Department of Conservation to restore indigenous aquatic fauna in one or more Te Arawa Lakes as a key component of both the traditional identity and practices of the Te Arawa people and the natural character of the lakes.

Draft project objectives

Restoration of the diversity and abundance of indigenous aquatic fauna in one or more Te Arawa Lakes to a level that

1. Provides a sustainable food source for Te Arawa, initially for ceremonial occasions but eventually as a kete kai[6] for Te Arawa generally.
2. Enables the revival of traditional practices and mātauranga Māori[7] relating to the indigenous fishery, enhancing the identity and mana[8] of the people of Te Arawa, and providing educational and tourism opportunities.
3. Enhances public awareness and appreciation of indigenous aquatic fauna as an integral component of the natural character of the Te Arawa Lakes.
4. Enhances New Zealand's aquatic biodiversity by providing a representative example of original natural character of lacustrine ecosystems in one or more Te Arawa Lakes.

Key considerations

Having developed the project goal and objectives, the Steering Committee turned its attention to the method of selection of an appropriate lake or lakes, and to identification and evaluation of ecological- and scale options for the project. The integrated nature of the project, seeking to meet both traditional cultural and contemporary biodiversity conservation objectives in a potentially hostile socio-political environment, makes this a complex task. In contrast to many contemporary conservation biology projects, in which a target population size for a particular keystone species can be specified, the goal for this project cannot be precise in this regard. The chosen lake and project scale should provide for a level of koaro harvest sufficient for traditional use, while achieving restoration of viable populations of desirable species using conventional ecological understanding of population dynamics.

In addition, the selection process for site and scale must anticipate and respond to the potential social conflict that will be generated by the need to remove trout and their associated forage food, common smelt, from the chosen lake or lakes. Social feasibility of an indigenous fisheries restoration project at any given lake will be largely determined by the scale of the ecological outcome that is sought at that lake, and in particular by the extent to which trout and common smelt will be controlled.

At the same time, the proposed development of a Community Participation Plan provides a means of positively influencing the social feasibility of the project.

The Steering Committee determined early on that there was a need to develop a decision support system to work through the various site and scale options. This was undertaken as Phase 1 of the project. An evaluation of options in accordance with the decision support system was then undertaken as Phase 2.

[4] Kawa - traditional cultural protocols.

[5] iwi as used here refers to a tribal confederation.

[6] 'food basket'

[7] traditional Māori knowledge

[8] authority, status and responsibility

Assumptions

The following assumptions underpin the project framework design:

- The species of interest as traditional foods are koaro, koura, and kākahi. Koaro will be specifically targeted for restoration initiatives because of both its position in the trophic scale as a top-order predator (on the assumption that there will be a cascade of benefits for desirable species through all other trophic levels), and its historical significance as a food resource.
- Common smelt, although similar to koaro and currently harvested to some extent, is not an adequate substitute species.
- Trout and common smelt are the main disturbance factors that require management.
- The project will be implemented in a series of phases, with restoration targets for each phase defined spatially and temporally.
- Options will be evaluated against cultural, ecological and social feasibility criteria.
- Ongoing monitoring of results will contribute to decisions on the design and implementation of each stage of the project, i.e. it will be based on the principles of 'adaptive management'.
- A Community Participation Plan focused on socio-political risks and feasibility of the project will be an integral component of its design.

PROJECT FRAMEWORK

The Project Framework (Fig. 2) is divided into three sequential but overlapping stages:

- Site selection and option identification,
- Project design and
- Implementation.

Sequential actions are shown in the grey boxes, and influences on each of these actions are shown in clear boxes with arrows indicating the direction of influence.

The fundamental importance of the Community Participation Plan is clear; it is operative through all stages of the project. The adaptive management approach is also clear, with the results of research and monitoring continually feeding back into ongoing project design.

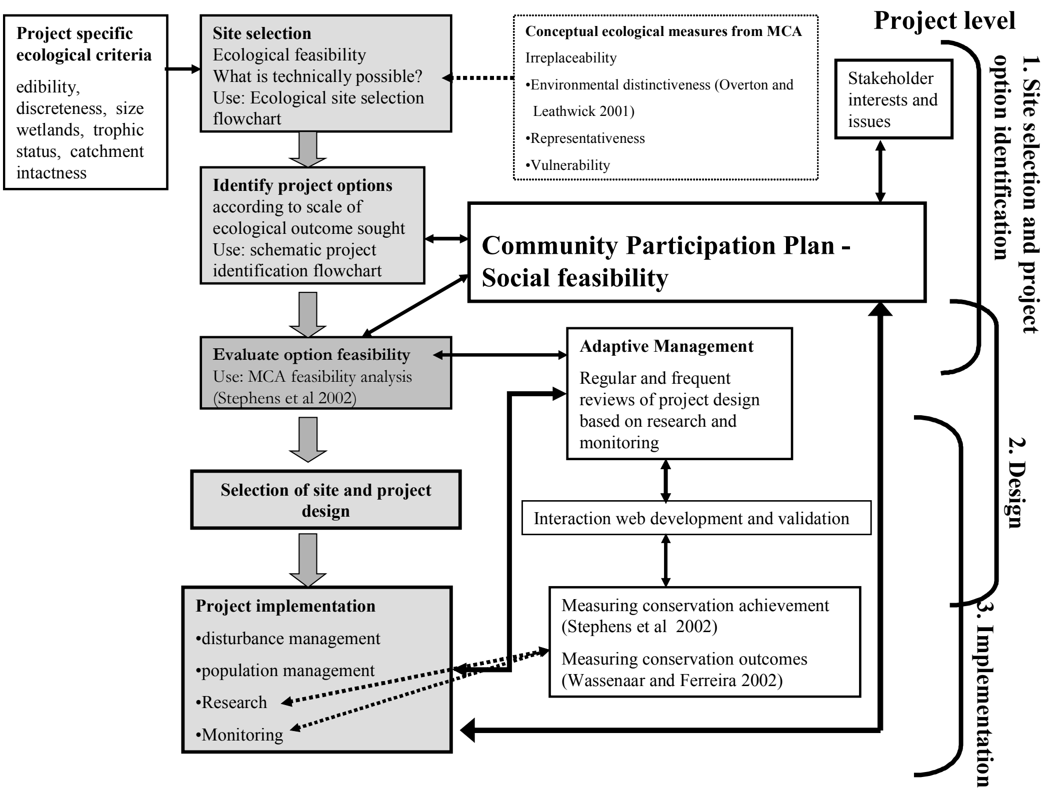

Fig. 2. Project Framework flowchart for the restoration of the Te Arawa Lakes, New Zealand.

Site selection and option identification

The DOC's emerging Natural Heritage Management System (NHMS) provides a starting point for site selection and option identification based on ecological achievability and social feasibility. Tools embodied in this system (Fig. 3) have been developed as a procedure for prioritising the DOC's conservation effort according to ecological principles (see Stephens *et al.* 2002).

A set of eight ecological and cultural criteria (Fig. 4) was designed by the Project Team to assess the suitability of an indigenous fisheries restoration project at each of the lakes in the Te Arawa Lakes complex. Assessment criteria are considered in two main classes. 'Fatal flaw' criteria are absolute, in the sense that any lake that does not meet such criteria is eliminated from further consideration – assessment against such criteria results in a 'Yes' or 'No' answer. 'Weighted' criteria are those against which a lake may be more or less favoured, but which do not result in elimination – they produce a 'Maybe' answer. For this project, most of the ecological and two out of the three cultural criteria are considered 'fatal flaw'.

In addition to the eight selected specific criteria, the contribution of a site to regional or national biodiversity can be estimated with tools provided by NHMS and described by Stephens *et al*. (2002). These tools all use environmental domains to provide the spatial context for assessment. Environmental domains are areas of similar environment (Overton and Leathwick 2001) defined by climate and landform variables derived from data describing soil type, slope, temperature, solar radiation, humidity and rainfall. These variables were chosen for their ability to account for much of the distribution of New Zealand's canopy trees, ferns and shrubs. Priority sites for conservation effort can be identified by measures of irreplaceability (derived from data used to classify environments) and vulnerability (derived from data describing human disturbance of environments).

At present, the ability to measure irreplaceability and vulnerability in freshwater systems, and therefore to compare the value of one lake with that of others, is limited. This is because an evaluation of key drivers for biodiversity within lake systems is not yet available and classification of aquatic environments awaits completion. It is anticipated that once environmental domains are generated for freshwater ecosystems, the above approach will be applied to the Te Arawa Lakes to determine how much an increase in biodiversity condition at the chosen site will add to national biodiversity. These measures are therefore included as 'sleeping' considerations, as shown in the dotted box of the Project Framework flowchart (Fig. 2).

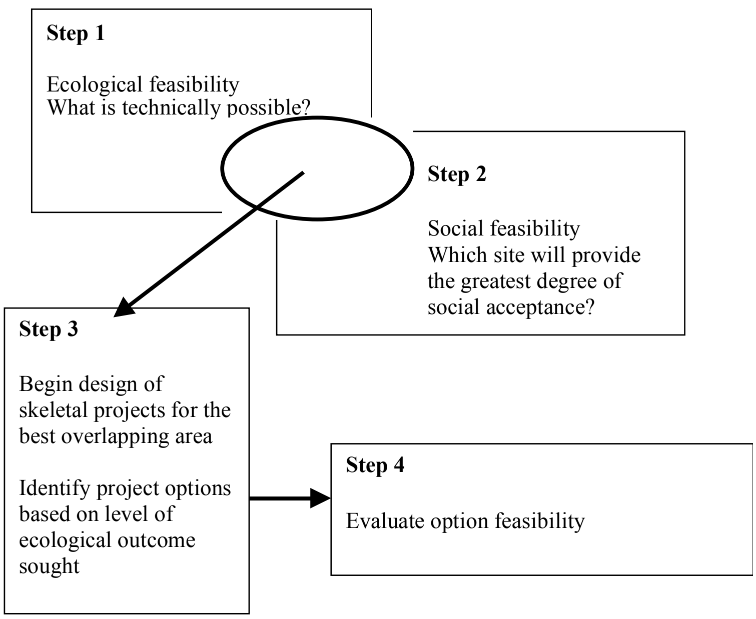

Fig. 3. Four-step process for site selection and option identification, Te Arawa Lakes project. Sites in the zone of overlap between Steps 1 and 2 are selected for skeletal project design and identification of project options in Step 3. At Step 4, the feasibility of these options is assessed in accordance with an assessment method that is also provided by the NHMS.

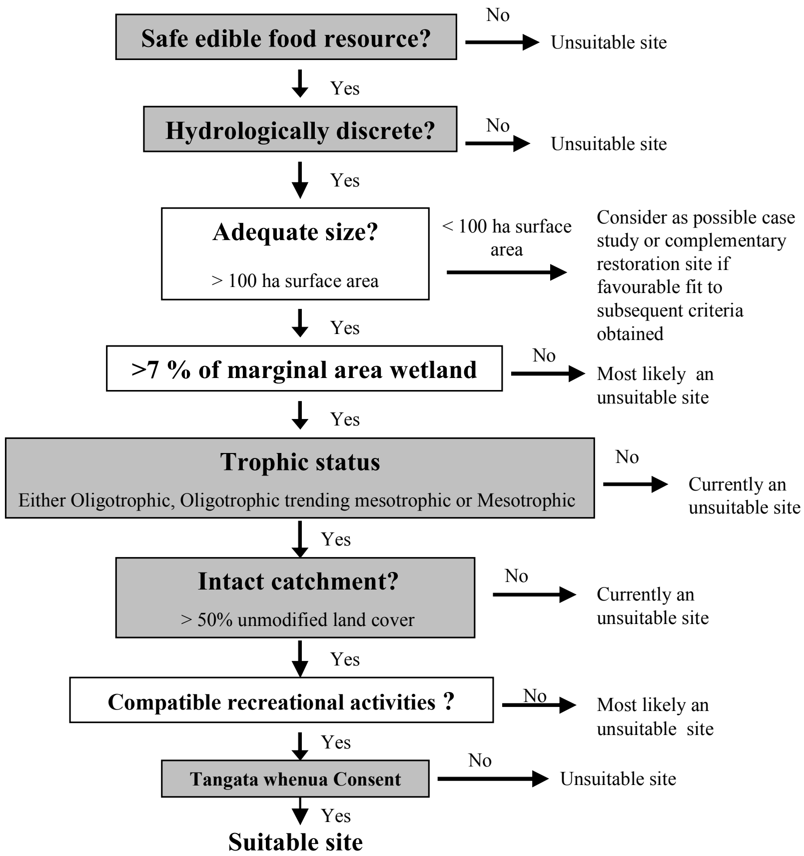

Fig. 4. Site-selection criteria flowchart**.** Fatal-flaw criteria shown in grey boxes.

Edible food resource

Objective 1 requires establishment of a sustainable cultural food source. Several Te Arawa Lakes are known to contain high concentrations of arsenic and mercury due to natural geothermal inputs. Arsenic and mercury accumulate in the flesh of fish and render them unsafe at high consumption levels. Lakes with high arsenic and mercury concentrations are eliminated from further consideration.

Assessment against this criterion is based on documented mercury concentrations in trout taken from the different lakes, and the resulting health advice regarding the safe volumes for consumption of trout servings on a per-month basis provided in Kim (1995).

Hydrological discreteness of system

Hydrological discreteness is the absence of connection by surface flow to other lakes. Discreteness of one lake from another significantly increases the chances of ecological success of the project by eliminating either the immigration of undesirable species (fish, weed and algae) and external influences (e.g. silt, sediment, nutrients, bacteria) to the selected lake, or the emigration of desirable species from it, or both. A lake meets this criterion if it has no surface connection with any other water body.

Hydrological discreteness is regarded as a critical requirement for ecological success of the project.

Adequate size

Adequate size is important to the achievement of both a sustainable food source and a worthwhile gain in biodiversity. However, it is acknowledged that both ecological and social feasibility are likely to decrease with increasing lake size.

Size is the surface area of the lake expressed in hectares. The Te Arawa Lakes fall neatly into 3 main size groups – more than 1000 hectares, 400–800 hectares, and less than 100 hectares. There is little information in the historical record about the extent to which small lakes of less than 100 hectares contributed to Te Arawa's food resources prior to European settlement of the Rotorua area. By contrast, the resources provided by large lakes such as Rotorua are well documented (Buck 1921). It is therefore unlikely that small lakes can fully meet the project goal and objectives, but they may add value to the project if either social feasibility considerations or a need for trial sites to advance ecological management skills necessitate a complementary or case study site. Small lakes that meet all other criteria are thus still considered as possible project sites for this purpose.

Marginal wetland associations

Marginal wetlands are known to be very important as habitat and spawning areas for a range of indigenous aquatic fauna, particularly koaro. The presence or absence of wetlands on lake margins is thus an important ecological criterion.

A value of at least 7% lineal proportion of the lake margin comprising wetland is used as a measure of fit for this criterion. This is based on the catch of koaro per unit effort in Lake Okareka, where the proportion of marginal wetland area remaining is slightly greater than 7%, being high in comparison with other Te Arawa lakes (Young 2002).

Trophic status

Habitat suitability for the suite of desired species is dependent on the maintenance within acceptable ranges of water quality parameters such as clarity, temperature and dissolved oxygen concentrations. These parameters are typically driven by nutrient concentrations in a lake, with higher concentrations often reducing habitat quality for freshwater fish.

Assignment of 'trophic status' is a method of classifying lakes according to nutrient concentrations and associated water-quality attributes. Lakes can be characterised along a continuum ranging from oligotrophic (nutrient-poor), through mesotrophic (moderately nutrient-rich) and eutrophic (nutrient-rich), to supertrophic (very nutrient-rich).

In general, most lakes begin as oligotrophic systems. Because of their wide variety in morphology, surface area, depth and natural inputs, however, all of which influence trophic status, it is unlikely that all the Te Arawa lakes were oligotrophic before the catchment modification that occurred after European settlement. It is reasonable to assume that most of them were somewhere in the oligotrophic–mesotrophic range. Rotorua, for example, has moved from mesotrophic to eutrophic status within the past 100 years, and Lake Okareka has shifted in just five years from mesotrophic to mesotrophic trending eutrophic (Burns 2001). Lakes of trophic status in the oligotrophic mesotrophic range were thus considered suitable to represent an original state of natural character.

Quantitative values for defining trophic status are provided by the Lakewatch monitoring programme undertaken by Environment Bay of Plenty as part of its Natural Environment Regional Monitoring effort (Burns 2001). Measurement is provided as a Trophic Lakes Index (TLI) numerical value, which correlates to trophic status. Lakes with a TLI of 2–3 are oligotrophic, 3–4 mesotrophic, 4–5 eutrophic and 5–6 supertrophic. Lakes require a TLI of 2–4 to meet the oligotrophic–mesotrophic criterion.

Catchment intactness

The degree of modification, and current land management practices in the lake catchment, can greatly influence both lake water quality and the physical structure of the habitat provided by lake margins and tributary streams. Ecological feasibility of the project is enhanced where catchments are less modified from an original state, and where current land management practices do not adversely affect water and habitat quality. The interdependence of lake and catchment also suggests that restoration will be easier in lakes where administrative aspects, such as tenure patterns in the catchment, are simple rather than complex.

There are, in addition, cultural, and social or 'experiential' considerations in relation to lake catchments. As a restoration endeavour this project is focussed on reviving both cultural and natural characteristics from an earlier time. Integrity of traditional practices will be enhanced if those practices can again take place in a setting resembling that in which they originally occurred. Natural character of a lacustrine ecosystem, and public appreciation and enjoyment of it, will likewise be enhanced where the wider lake setting retains a high level of natural character.

'Catchment intactness' is considered to be the extent to which original native vegetation still exists in the lake catchment. This is measured as the proportion of the vegetation cover in the catchment that is native, and is derived from the 1998 National Land Cover Database. A proportion of more than 50% native vegetation remaining in the catchment is used as the threshold for this criterion. This is based on the assumption that conversion of more than 50% of the native vegetation in a catchment will detract excessively from the natural character of the lake, and that both ecological and administrative issues arising from catchment modification above this level will be difficult to manage.

Compatible recreational activities

The 'Catchment Intactness' criterion incorporates cultural and social considerations in respect of the physical setting within which the project will be undertaken, but does not address existing human activities at the site, and the extent to which they are compatible with the revival of traditional cultural practices. So integrity of traditional practices will also be enhanced if those practices can be carried out in a setting that is reasonably free of intrusion by potentially disruptive modern recreational activities including jet skiing, water skiing, and so on. Under this criterion consideration is given to the types of recreational activities that currently occur, their intensity, and the size of the lake. A judgement can then be made about the extent to which the activities detract from or are compatible with experiential aspects of its natural character.

Tangata whenua consent

Given the partnership nature of this project, any lake that does not have iwi or hapu[9] consent is ruled out of contention as a possible project site.

Summary of results

All 17 named lakes in the Te Arawa Lakes complex were considered as possible restoration sites and were evaluated against the criteria flowchart. Preliminary evaluation shows that only one of these meets all 8 criteria. In addition, one small lake met all criteria except for size, and was therefore identified as suitable as a possible case study or complementary site in the event that one is required.

Design

At any site that meets the site-selection criteria, there is a range of options available for project design in terms of both spatial scale and level of ecological manipulation.

Spatially, ecological manipulation may be undertaken in tributary streams, or in both tributary streams and the lake. Consideration also needs to be given to whether translocation of the desired species may be necessary, because remnant populations of these species are either significantly depleted in comparison with their historical abundance, or locally extinct. In terms of ecological manipulation, there are a number of options for control and restoration. The possible combinations of spatial scale and level of manipulation then give rise to a spectrum of design possibilities (Fig. 5).

A considerable number of options is theoretically possible at any site. Of that number, however, only a limited selection contains real options when tested against the question, "Would you actually do that?" Implicit in the application, then, is a 'reality check' that sieves out options for which the answer to this question is 'No'.

Feasibility assessment

Once agreement has been reached on sites and project options, feasibility of each option can be evaluated. A toolset developed to Measure Conservation Achievement (Stephens *et al.* 2002) within the Natural Heritage Management System offers a relevant and robust method for feasibility assessment. The framework has therefore adopted this assessment approach in its entirety and is partially reproduced here by courtesy of the authors.

Procedure for weighting outcome feasibility (from Stephens *et al.* 2002)

All conservation projects are subject to risk. Five risk factors contributing to outcome failure were identified:

- ***Outcome risk***: the risk that planned actions are not appropriate to achieve the outcome sought, usually because the conservation problem is not understood well enough to identify appropriate courses of action.
- ***Operational risk***: the risk that unexpected events cause insufficient project implementation to achieve the intended outcome. A complex work environment, poor planning, contingencies, inadequate resources or weak commitment are major sources of operational risk.
- ***Legal risk***: occurs when other stakeholders can determine whether a project (or some of its components) can be implemented. Legal access and resource consent requirements are sources of legal risk.
- ***Collateral-damage risk***: occurs when an action has adverse effects on other natural heritage assets, as may occur in a pest-control operation that causes some by-kill of native species or leaves toxic residues.
- ***Socio-political risk***: the risk that public concern and opposition limit or prevent project implementation. Effective public consultation and involvement are important in the management of socio-political risk.

Just two attributes of each risk need to be evaluated to quantify project feasibility: the effect (E) of the risk factor on the project outcome and the proportion (P) of this risk that is effectively managed.

[9] Hapu is a sub-tribe or extended family group that relates to a more discrete area than does the wider iwi.

Feasibility with respect to one risk factor can then be measured by

Feasibility = 1 – (E – ($E \times P$))

Project feasibility is the product of the individual feasibility values for each risk factor. E and P for each risk factor are quantified by asking the project manager the following sequence of questions:

- Is this risk factor an issue for this project? If No, then E = 0 and P = 0; move on to next risk factor. If yes, go to 2.
- If the risk is not managed, and it eventuates, what proportion of the outcome will still be achieved? If none, then E = 1. If only half (e.g. conservation goal achieved over only half the area), then E = 0.5.
- What proportion of this risk can be effectively managed? If all, then P = 1. If E is negligible, then there is little benefit in expenditure aimed at managing this risk, so P is likely to be small.

PRESENT STATUS

To date, the project has progressed to the point of preliminary site selection and identification of options for that site. A feasibility analysis for each option now needs to be run.

Another key step not yet undertaken is a community-relations workshop to identify socio-political risks and opportunities, and to map out a program – the Community Participation Plan, for engaging other stakeholders in the project from this point on.

Settlement of the Te Arawa Lakes Claim is currently being negotiated. This project is presently on hold pending final settlement of the claim.

CONCLUSIONS

Partnership

The partnership between contemporary science and a traditional cultural approach requires preparedness on the part of agency staff to move away from well-established organisational ways of working, which are generally focused on meeting pre-determined conservation-management goals. A willingness to embrace different cultural perspectives and to adopt different ways of doing things is essential. This

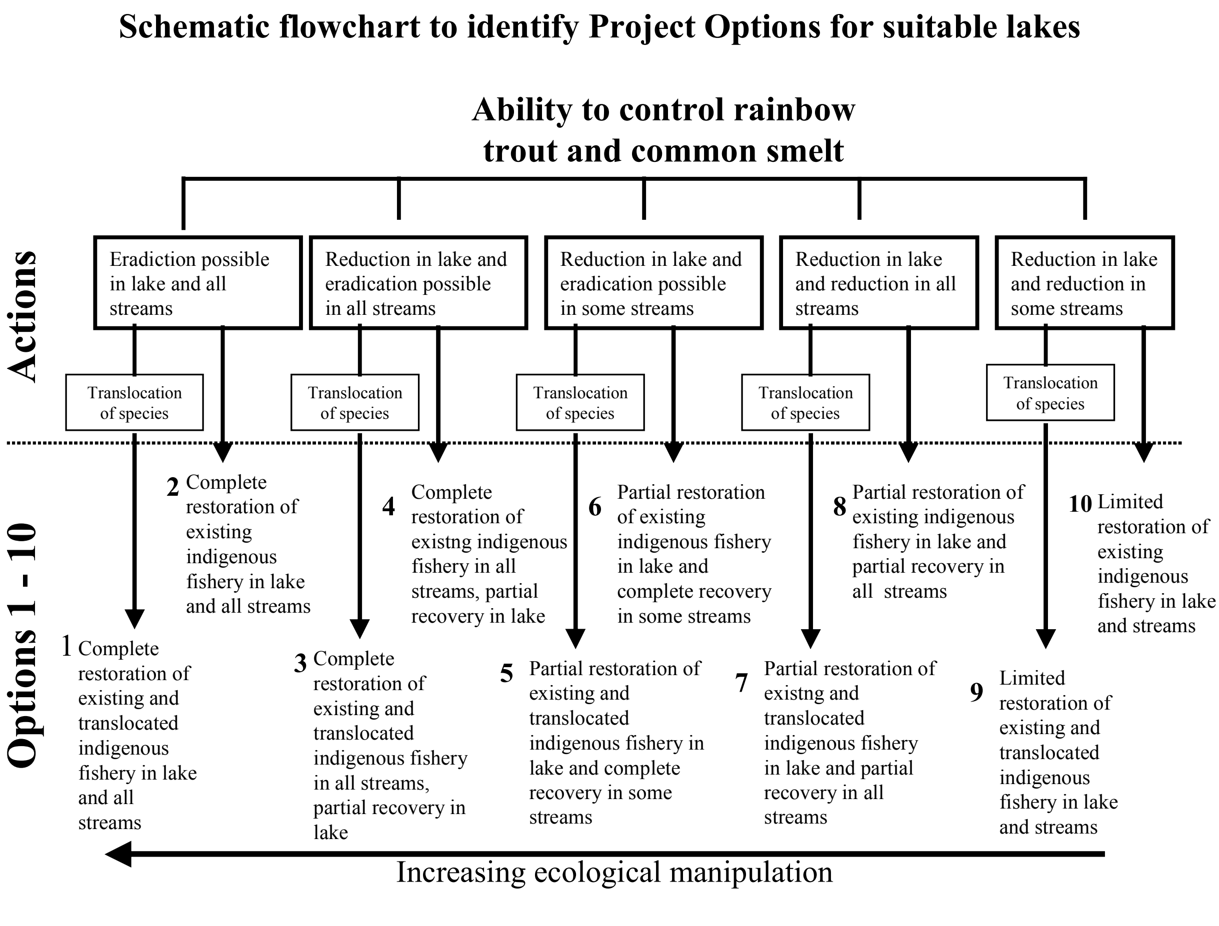

Fig. 5. Project options based on degree of ecological manipulation and spatial scale.

requirement may take staff out of their comfort zones. A partnership should also involve willingness by society more generally to re-evaluate environmental management goals and take into consideration Treaty Partner values and aspirations. This project addresses a re-evaluation of lake use priorities.

The project recognises the traditional cultural significance of indigenous freshwater aquatic biodiversity and incorporates cultural imperatives in a project focused on its restoration. This approach is expected to build a stronger support base for the project initially, and to enhance prospects for its long-term sustainability. It is already yielding dividends, establishing a solid base for a durable working relationship with iwi, who are set to become major resource managers through the outcomes of Treaty settlements. In addition, iwi capacity to undertake resource management functions will be enhanced through the experience in contemporary science gained on this project.

Process

In the absence of a pre-determined goal and associated objectives at the outset, the framework provides a transparent decision support system to guide site selection, identification of project options, and evaluation of option feasibility. A number of toolkits are being developed by the DOC to prioritise and optimise conservation gains achievable within present resourcing levels. Incorporation of these into specific projects such as this strengthens the rigour of the assessment and decision-making process. The development of a Community Participation Plan as an integral component of the framework is critical to success of the project in circumstances where the actions necessary to achieve it are potentially socially and politically contentious. The adaptive management approach allows for continual review and adjustment of project design and implementation.

Science

Traditional resource management practices included the use of such mechanisms as *rāhui*, a temporary prohibition on harvest of a resource to allow time for its natural replenishment. Examples of traditional approaches to restoration of resources severely degraded not only by excessive harvest but by a range of other human-induced disturbances (e.g. introduction of alien species and removal of habitat) are lacking. As a contemporary science discipline, however, restoration ecology specifically addresses the need to analyse and design responses to severe ecosystem degradation. The use of this tool is therefore entirely appropriate to assist recovery of indigenous resources where their decline is attributable primarily to large-scale post-European disturbance.

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FISH HABITAT AREA NETWORK IN QUEENSLAND, AUSTRALIA – AN INNOVATIVE AQUATIC PROTECTED AREA APPROACH

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Abstract

The management of Queensland's fisheries is based on a combination of input controls, output controls and fish-habitat conservation measures intended to achieve fisheries sustainability. The declaration and ongoing management of Fish Habitat Areas (FHAs) is a key element of this management strategy. FHAs are a multiple-use form of Aquatic Protected Area that aim to protect key areas of coastal and estuarine fish habitat from the impacts of coastal development while allowing for the continuation of community use and legal recreational, commercial and traditional fishing. It is estimated that 75% by weight and 80% by value of Queensland's commercial fishing catch, and a significant proportion of the recreational and traditional catch, are derived from species that spend part of their life cycle in estuarine waters.

The FHA program, which commenced during the late 1960s, provides protection for more than 714 000 ha of coastal and estuarine fish habitats. The FHA network contains 37% of Queensland's estuaries, 42% of the mangrove habitat on the east coast and a significant proportion of the State's saltmarsh habitats, and includes representation of many of the shoreline habitat types.

Strong support from the fishing industry and the community for the FHA program has resulted in its broad distribution and strong management and its influence over Queensland's coastal planning and management.

Keywords: fish habitat area, marine protected area, fisheries management, Australia, coastal management

INTRODUCTION

Fishing and seafood consumption are integral components of the Queensland lifestyle and culture. Commercial, recreational and traditional fisheries occur along the length of the Queensland coast and contribute to the economic viability of many coastal communities.

The State's 1700 licensed commercial fishers harvest seafood for local and interstate consumption and for export. Commercial fisheries have an annual Gross Value of Production (GVP) of approximately AUS$295 million, based on prices paid to commercial fishers at the wharf (Williams 2002).

More than 800 000 Queenslanders (28% of the population aged >5 years) fish recreationally at least once per year (Higgs 2001). These recreational fishers spend around AUS$300 million per year on fishing and associated activities and harvest around 8500 t of fish, crabs and prawns annually (Williams 2002).

Ecologically sustainable development (ESD) of fisheries is a management objective of all Australian fisheries management agencies. The Queensland *Fisheries Act* 1994 captures the concept of ESD as its primary legislative objective. From a fisheries perspective, Queensland is fortunate to have 6 080 km (Zann 1995) of tropical and subtropical coastline, diverse, extensive and relatively undisturbed fish habitats, clean water, abundant fisheries resources, a high standard of living, and a relatively small human population dependent on these coastal resources. These environmental and sociological attributes provide tremendous opportunity for proactive fisheries and environmental management practices to ensure that Queensland's marine fish stocks and fisheries remain sustainable into the future.

Fisheries management in Queensland is based on a combination of input controls (e.g. gear restrictions, and seasonal and temporal closures), output controls (e.g. size limits) and fish habitat conservation measures developed and implemented to achieve the objective of fisheries sustainability.

The subject of this paper, the Queensland Fish Habitat Area (FHA) network, has been central to Queensland's fisheries management and fish habitat conservation since the inception of the network during the late 1960s. In this paper we provide a history of the State-wide FHA network, discuss why estuarine and coastal habitats are the focus of FHA protection, analyse the habitat types within the network, look at the benefits of reactive and proactive declarations, outline the criteria for FHA selection, provide an overview of FHA management, and discuss the issues that will influence the future direction of the FHA network.

HISTORY

The links between fish habitat and fisheries productivity have long been accepted by the scientific community, many recreational and commercial fishers, environmentalists and some members of the broader community. Queensland fisheries legislators initially recognized the importance of protecting fish habitat to sustain fisheries, with the adoption of statewide protection of mangroves under the *Fisheries Act* 1957. Mangroves had been provided a level of protection since 1914. However, this was specifically to maintain their value to the oystering industry and it was not until the 1957 legislation that the mangrove protection formally recognized the broader fish habitat values of coastal vegetation (Zeller and Beumer 1996).

During the 1960s, 1970s and early 1980s, southern Queensland was the focus of substantial development within its coastal fringe. Impact assessment for these developments was limited, in comparison with current standards, and a significant number of developments achieved approval within and directly adjacent to coastal fish habitats. Although mangroves (and other tidal plants from 1976 onwards) were protected, permits for their disturbance could be, and were, granted. Extensive canal developments in the southern Moreton Bay / Gold Coast region are illustrative of this development period, and they combined with other coastal development to result in the loss of 8.4% (1361 ha) of mangroves and 10.5% (592 ha) of saltmarsh within the region from Coolangatta to Caloundra between 1974 and 1987 (Hyland and Butler 1988).

During the mid 1960s, the concept of complementing mangrove protection with the protection of key, spatially defined areas of fish habitat was developed to counter the impacts of encroaching coastal development. The legislative framework for these protected areas, termed Fish Habitat Reserves, was achieved with the *Fisheries Regulation* 1968. The purpose of the Regulation was to provide a form of protection for areas of fish habitat deemed to be of importance in providing food and shelter for marine fauna, for localities such as recreational fishing areas, commercial hauling grounds, and for areas considered worthy of conservation for education and scientific study (Olsen 1977). All habitat types (i.e. vegetated and unvegetated) within the boundary of a Fish Habitat Reserve were to be afforded an equal, high level of protection from physical disturbance or alteration.

Using current terminology, Fish Habitat Reserves were 'multiple use' aquatic protected areas, focused on protecting natural fish habitats from alteration and degradation whilst allowing for community use of the Area, including a continuation of legal fishing activities. The Fish Habitat Reserve concept with its 'multiple use' philosophy was strongly supported by the recreational and commercial fishing sectors. This strong industry support, coupled with straightforward consultation and declaration processes, resulted in the declaration of 23 Fish Habitat Reserves by 1977 (Zeller and Beumer 1996). These Reserves covered more than 70 000 ha of tidal fish habitats within Moreton Bay, Maroochy River, Noosa River, Great Sandy Straits, Corio Bay and Hinchinbrook channel.

Declaration of a Fish Habitat Reserve was not a precursor to additional fishing closures. Other than for some bait species (e.g. molluscs), the status of an area as a Fish Habitat Reserve was never used by Queensland fisheries managers as justification for increasing the management restrictions on fish stocks within the declared area.

In 1982, the fisheries legislation was amended to provide for the declaration of Wetland Reserves. The new type of reserve served a similar purpose to that of the Fish Habitat Reserve but allowed for activities with a slightly higher level of impact. Wetland Reserves were declared in areas which contained high-quality fish habitats, but which had existing or proposed adjacent land uses that were incompatible with the more stringent Fish Habitat Reserve protection and management. A number of Wetland Reserves were also declared between development nodes and core conservation areas (Fish Habitat Reserves). The Wetland Reserve management was more flexible, but ensured that the fish habitat values within the declared area were a primary consideration when any development activity within or adjacent to the area was considered.

By 1994, the fisheries reserve network had been extended, with 48 Fish Habitat Reserves and 30 Wetland Reserves successfully declared throughout the State, protecting over 600 000 ha of quality coastal and estuarine fish habitats.

In 1994 the current *Fisheries Act* was proclaimed. This legislation combined Fish Habitat Reserves and Wetland Reserves to a single broad category, Fish Habitat Areas (FHAs). In practice, this change has been in name only and has not altered the two-tiered management approach or the philosophies behind the fisheries reserve concept. Fish Habitat Reserves are now 'A' Management FHAs, and Wetland Reserves are 'B' Management FHAs. Currently, 714 000 ha of fish habitats are protected within the 74 declared FHAs. A number of amalgamations of existing FHAs have occurred since 1994.

THE COASTAL AND ESTUARY FOCUS

Estuaries and coastal habitats are vital nursery grounds and important habitats for feeding and reproduction of many fish species (Blaber 1997). It is estimated that 75% by weight (or 80% by value) of the commercial fishing catch in Queensland is derived from species that spend part of their life in coastal and estuarine waters (Quinn 1992). As recreational and traditional fishers target many of the same species as the commercial fishers, both these stakeholder groups are also highly dependent upon these habitats.

Queensland's commercial and recreational fisheries occur around the entire coastline, from the Northern Territory border around the Gulf of Carpentaria to Cape York, then south through the Great Barrier Reef to the New South Wales border (Williams 2002). Coastal and estuarine fish habitats, even in the most remote localities on the Queensland coast, are directly supporting substantial fisheries. For example, the coastal habitats of West Cape York and the Gulf of Carpentaria are recognized as important prawn nursery grounds that support the Northern Prawn Fishery, which has an annual harvest of around 8000–10000 tonnes (Pownall 1994).

The threat of ongoing loss and degradation of vital coastal and estuarine fish habitats as a result of coastal development was the stimulus for commencing the FHA network, and still remains the primary objective of FHA management 34 years later. FHA management has evolved to focus on and deal with the issues that affect coastal and estuarine fish habitats. As Queensland's offshore habitats are different physical environments and are subject to very different pressures, the current FHA management focus on protection from direct development-based impacts is not particularly relevant to these offshore fish habitat types. There is scope to extend the FHA network into freshwater environments, where impacts of development (e.g. from some agricultural practices and urban expansion) are a major factor in the quality of freshwater fish habitat. However, a number of modifications to the existing FHA management approach would be required to ensure that FHAs in the freshwater environment were effective and could achieve community acceptance.

With 85% of the Queensland population living along the coast and the population steadily increasing, it is suggested that pressure on coastal and estuarine habitats will continue to increase (Environmental Protection Agency 1999). Improved technology (e.g. tertiary treatment of sewerage) may provide many positive environmental outcomes, but it appears likely that a net increase in pressure on our inshore and estuarine fish habitats will still occur. The importance of retaining this environmental capital to ensure ongoing fisheries production cannot be overstated.

By their nature and location, FHAs are often not low-conflict, remote sanctuaries with straightforward management. They influence development planning and challenge the community to recognize and protect the habitats that are present in their "backyards". Declaration and management of FHAs requires a detailed understanding of local issues and a 'grass roots' approach to dealing with the community.

ANALYSES OF HABITATS WITHIN THE NETWORK

Australia's marine waters have been classified into 60 ecosystem-scale bioregions by the Interim Marine and Coastal Regionalisation (IMCRA) scheme (IMCRA Technical Group 1997). Eight of these bioregions capture Queensland's coastal and estuarine waters. This ecosystem classification scheme has received broad acceptance by MPA practitioners throughout Australia and provides a useful tool for analysing and discussing the distribution and representativeness of habitat types protected by the FHA network.

FHAs are present within seven of the eight Queensland coastal bioregions, the exception being West Cape York (Table 1). The fish habitats on the Queensland east coast (New South Wales border to Cape York) have been the major focus for FHA declaration, with 95% of the FHA network, by area, being present within this section of the coast. The level of FHA protection on the east coast is directly related to the higher population and development pressures within these coastal areas and the primary objective of the FHA network to protect fish habitats from these pressures.

Defining the area of declared FHAs within bioregions is an indicator of the extensiveness and regional representativeness of the network. However, area alone is not necessarily indicative of whether the network is representative of different habitat categories. The following sections provide an analysis of some of these habitat categories present within the FHA network.

Table 1. Relative distribution within bioregions of total area of declared FHAs and estuaries within FHAs.

Queensland Coastal Bioregion[1]	Total area of declared FHA (ha)	Number of estuaries partially or totally within FHAs
Tweed – Moreton (NSW border – Seventeen-Seventy)	109 969	18 (58%[1])
Shoalwater Coast (Seventeen-Seventy – Mackay)	222 767	25 (47%[1])
Lucinda – Mackay Coast (Mackay – Lucinda)	257 074	26 (52%[1])
Wet Tropic Coast (Lucinda – Cooktown)	26 788	10 (32%[1])
East Cape York (Cooktown – Cape York)	58 035	19 (41%[1])
West Cape York (Cape York – Aurukun)	0	0
Karumba – Nassau (Aurukun – Burketown)	33 484	9 (21%[1])
Wellesley (Burketown – NT border)	5 690	8 (24%[1])
Total	713 807	115 (37%[1])

[1]Percent of total number of estuaries within bioregion.

Data Sources: FHA Data - Queensland Department of Primary Industries FHA dataset (DPI-1 2001)
Estuaries Data - Queensland Estuaries from the Australian Estuaries database (AGSO 2001)

Table 2. Relative spatial distribution of habitat categories within declared FHAs captured by each Queensland coastal bioregion.

Queensland Coastal Bioregion[1]	Area of seagrass within declared FHA (ha) [1]	Area of mangrove within declared FHA (ha)	Area of saltmarsh /saltpan within declared FHA (ha)	Shoreline Habitat types within declared FHA
Tweed – Moreton	17 005	18 714 (57% [2])	4 256 (47% [3])	16 (66%[4])
Shoalwater Coast	2 201	34 921 (41% [2])	18 870 (22% [3])	20 (80%[4])
Lucinda – Mackay Coast	4 336	19 630 (39% [2])	4 985 (13% [3])	28 (93%[4])
Wet Tropic Coast	1 309	11 720 (34% [2])	60 (4% [3])	6 (24%[4])
East Cape York	4 936	17 855 (42% [2])	24 238 (62% [3])	14 (56%[4])
West Cape York	N/A	N/A	N/A	N/A
Karumba – Nassua	0	1685 (4%[2])	979 (<1%[2])	6 (66%[4])
Wellesley	0	191 (2%[2])	512 (<1%[2])	5 (21%[4])
Total	29 787	104 716	53 900	

[1]Seagrass distribution can change seasonally and between years.
[2]Percent of total area of mangrove vegetation within bioregion.
[3]Percent of total area of saltmarsh / saltpan vegetation within bioregion.
[4]Percent of total number of shoreline habitat types within bioregion

Data Sources: Seagrass Data – Department of Primary Industries Seagrass Meadows 1984–88 dataset (DPI – 2 2002).
Mangrove and Saltmarsh Data – Department of Primary Industries Queensland Coastal Wetland Mapping Project dataset (DPI -3 2000).
Shoreline Data – Environmental Protection Agency Shoreline Classification of Queensland (EPA 2001).

Estuaries

Estuaries support a diversity of fish habitats including open water, unvegetated tidal flats and channels, rock and point bars, saltmarsh, mangroves and seagrass beds (Zeller 1998). Their importance to Queensland fisheries production has been outlined above. More than 300 separate estuaries have been identified along the Queensland coast (Zeller 1998). Of these, 37% are partially or entirely captured within the declared FHA network (Table 1).

In each of the eight coastal bioregions except the West Cape York bioregion, at least 21% (ranging up to 58%) of the estuaries are partially or completely protected by FHA management (Table 1).

Vegetated Habitats

Estuarine and inshore vegetation communities (e.g. mangroves, saltmarsh, seagrass) serve a variety of functions essential for sustaining fish communities and fisheries. These functions (Short 1987; Claridge and Burnett 1993; Ewel *et al*. 1998; McKenzie *et al*. 2000) include:

- Nutrient uptake and transformation;
- Primary carbon production in estuarine food chains;
- Provision of food, shelter, breeding and nursery areas for a variety of fish, mollusc and crustacean species; and
- Sediment stabilization and physical protection of the coastal fringe from erosion and flooding.

Presence and diversity of vegetated habitats within a waterway appear to positively influence fish diversity and abundance. For example, Bell and Pollard (1989) suggested that the diversity and density of fish is usually higher in seagrass than in nearby bare areas, and Robertson and Blaber (1992) found that the presence of seagrass beds in mangrove-dominated estuaries appears to enhance fish species richness. Although these studies support the importance of marine plants as a fish habitat, this habitat does not function in isolation and must always be considered as part of the complex, larger estuarine and inshore habitat mosaic.

Mapping of vegetated habitats within Queensland's coastal and estuarine environments has been undertaken at various scales. The availability of these data allows analysis of the extent of vegetation protected by FHAs within each coastal bioregion (Table 2).

Seagrass communities are dynamic and may undergo substantial change in response to seasonal variation and environmental factors (Zeller 1998; McKenzie *et al.* 2000). These factors, combined with the time required to map the distribution of these predominantly submerged plant communities, make it difficult to determine the seagrass distribution for the entire coast at a single point in time. The seagrass data presented (Table 1) are a compilation of the results of an extensive survey program conducted by DPI between 1984 and 1988 and is the most complete data set of estuarine and coastal seagrass communities available. The area of approximately 30 000 ha of seagrass recorded within FHAs during these surveys was all on the east coast. For the reasons outlined above this information should be considered as only an indicator of its present distribution.

In contrast to the seagrass communities, the distributions of mangrove and saltmarsh vegetation are significantly less vulnerable to seasonal and environmental variations. This allows for existing data on the distribution of these communities to be used with a higher level of confidence in terms of reflecting the present situation. The mangrove and saltmarsh data used for this analysis are based on satellite imagery from 1995 and 1997.

On the east coast, approximately 42% of the total area of mangrove vegetation is protected within FHAs. This high-level representation of mangroves within FHAs is evenly distributed through each of five east coast IMCRA regions (refer to Table 2). This contrasts significantly with West Cape York and Gulf of Carpentaria where less than 2% of the total area of mangroves is within declared FHAs.

The presence of saltmarsh / saltpan within FHAs follows a similar pattern, with approximately 30% of the saltmarsh / saltpan on the east coast protected within FHAs and <1% in the West Cape York and Gulf of Carpentaria region.

Unvegetated habitats

All natural habitats within a FHA, whether vegetated or unvegetated, are considered to be vital components of the larger coastal and estuarine habitat mosaic and are afforded the same level of protection by the FHA declaration and management.

Approximately 65–70% of the total area of declared FHAs in Queensland is unvegetated tidal waterway (brackish, estuarine and near-shore marine) or unvegetated intertidal land. The broad category of unvegetated habitats includes a diverse range of habitat types which are present within the FHA network, such as surf beaches, rocky reefs and headlands, sand bars, mudflats, undercut banks, deep holes, etc. These are essential fish habitats, with many of the species caught by commercial and recreational fishers targeted in unvegetated habitats (e.g. tailor, flathead, whiting, banana prawns, etc.). Erftemeijer and Lewis (1999) recognized that intertidal mudflats constitute an important habitat that supports a high biodiversity and biomass of benthic invertebrates, which sustain fisheries.

Classification and mapping of the Queensland intertidal shoreline has identified 32 natural alongshore habitat categories (Banks and Skilleter in press). Table 2 provides the results of a GIS analysis of the presence or absence of each intertidal alongshore habitat type within the FHA network per IMCRA bioregion. Detailed analysis of these shoreline data (i.e. beyond the basic presence and absence analysis undertaken for this paper) is required to provide the basis for discussion on the representativeness of the FHA with regard to shoreline habitat type. However, the values provided in Table 2 indicate that a significant proportion of the natural shoreline habitat types within many of the IMCRA regions are present within the FHA network.

SELECTION OF FHAS

The FHA network has been developed by a fisheries management agency. The mandate or philosophy of the agency responsible for developing a Marine Protected Area will determine its primary purpose and, in turn, determine the selection criteria or targets that are used to achieve that primary purpose (Thackway 1996). Unlike MPAs declared for other purposes (e.g. biodiversity conservation) the presence of fishing activities within a FHA is viewed positively and is a direct indicator that the area is a productive fish habitat, likely to be worthy of long-term protection.

When assessing a candidate area of coastal and estuarine habitat for FHA declaration, the following fisheries resource and habitat attributes are currently considered indicative of an area that warrants ongoing FHA protection:

Fisheries resource criteria

- Contains high fish species richness.
- Contains a high diversity of regionally targeted species (juvenile or adult).
- Supports existing fisheries within its boundary.
- Supports external / regional fisheries.

Habitat criteria

- Large size.
- Contains diverse habitat types.
- Limited existing disturbance from instream artificial structures.
- Good water quality.
- Adjacent riparian buffer zone is generally in good condition.
- Disturbance to fish passage and flows from upstream water impoundment structures is limited or reducing.
- Limited disturbance currently proposed within the Area.
- Contains regionally unique fish habitat features.

It is recognized that a candidate FHA will rarely meet all of the above criteria and therefore a level of interpretation is required with their application. The criteria are straightforward, are relatively easy to assess, and can be understood by the general community. These attributes of the FHA selection criteria are becoming increasingly important as the Queensland community has a high expectation of involvement in and understanding of the basis of any government decision that alters or affects future planning within their local region (e.g. FHA declaration).

REACTIVE AND PROACTIVE FHA DECLARATIONS

Selection of new FHAs was initially reactive and driven by the need to provide increased protection of high-quality fish habitats within areas that were subject to ongoing development pressures (Olsen 1977). All FHA declarations attempt to engender community understanding of the values of fish habitats, create a sense of community ownership of their fisheries resources, and provide a strong legal framework for their protection. Over time, the network has evolved, providing a base for a more strategic approach to its planning. It has been recognized that additional benefits can be derived from declaring FHAs in areas that are not currently the subject of significant development pressures and creating a network that is more regionally representative. This philosophy is supported by current Australian Marine Protected Area (MPA) planning philosophies, which recommend that the national MPA network should be comprehensive, adequate and representative (TFMPA 1999).

Proactive FHA declarations have been successful in many areas currently subjected to a low level of threat from coastal development such as Cape York, the Gulf of Carpentaria and the region north of Cairns. A significant benefit of proactive declarations is that the process generates community support and interest in fisheries sustainability and fish habitat protection well before the community's desire and resolve to protect this habitat is challenged by development pressure.

FHA DECLARATION

Extensive community and stakeholder consultations are conducted prior to the declaration of a FHA. Consultation occurs over a period of 12–24 months, depending on the complexity of issues to be addressed, and follows a standardized, transparent process.

The consultation is intended to inform the community and stakeholders of:

- The fisheries and fish habitat values of the area;
- The benefits and restrictions of FHA management; and
- The FHA management options available (A or B Management levels).

Consultation also gathers information on:

- Existing and planned uses within and adjacent to the area;
- The suitability and acceptability of the proposed FHA boundary locations and management level/s; and
- The overall level of support for the proposal.

At least two opportunities for community and stakeholder input are provided as part of every FHA consultation process. As the FHA network has been developed by an iterative process of declaring smaller focused areas (rather than attempting to declare large regions in a single process) consultation periods can be highly focused on localized issues and departmental representatives can actively participate in community debate at all levels. This has been an important element in the success of many FHA declarations because the community has a genuine feeling of participation and the opportunity to develop trust in the declaration process and those responsible for its delivery and subsequent management.

Declaration of a FHA requires amendment of the *Fisheries Regulation* 1995 by the Executive Council of the Queensland Government (Cabinet) who consider the outcomes of the consultation process as an integral part of their decision.

The consultation process regularly results in the negotiation of minor boundary amendments and occasionally the downgrade of the initially proposed management level, but FHA proposals generally receive broad community support. Only on one occasion has a proposed FHA met with substantial enough opposition during its consultation period for the government to decide not to progress to declaration. This occurred in the late 1990s with a FHA proposal over part of the Calliope River near the industrial, port city of Gladstone in Central Queensland. The proposal met with strong support from the community and fishing interests. However, intense opposition from pro-development interests resulted in the FHA proposal being deferred indefinitely.

OVERVIEW OF THE MANAGEMENT

FHAs are declared as either, or a combination of, 'A' or 'B' management levels. The two-tiered management approach recognizes that important fish habitats occur within locations

- Where very strict FHA management arrangements can be achieved, and
- Where the FHA management must recognize that existing or planned uses of some Areas or their surrounds require a more flexible management approach.

Although normal community use and activities (including legal fishing activities) are not restricted by FHA management, any works or activities requiring the disturbance of habitats within a FHA require impact assessment and the issue of a specific permit under the provisions of the *Fisheries Act* 1994. A summary of works or activities (other than normal community use) that may be permitted within each level of FHA management is provided (Table 3).

During the four-year period between 1998–2001, on average 18 permits per year were granted for works or activities within declared FHAs. All these permits have been granted within FHAs on the Queensland east coast and almost 50% were for works within FHAs of the Tweed–Moreton coastal bioregion. This again illustrates the higher development pressure within southern Queensland and the extensiveness of the coverage of the FHA network in this area.

The small numbers of permits granted each year were for works or activities that were assessed as compatible with the FHA management (Table 3). During the 1998–2001 period approximately 30% of permits were issued for maintenance of existing structures, 18% for the construction of jetties, pontoons and boat ramps, 16% for erosion control and beach protection, 10% for aquaculture activities, and the remainder for a variety of other minor-impact activities. The majority of permits for construction activities were granted within B-management-level FHAs.

Table 3. Summary of works or activities that may be authorized by permit within each FHA management level.

'A' Management Level	'B' Management Level
Limited impact construction of facilities for 'a fisheries purpose' (e.g. public boat ramps, public jetties). Maintenance of existing facilities. Construction of educational facilities (e.g. boardwalks). Scientific research. Works for public health and safety reasons. Restoration of disturbed fish habitats. Construction of public facilities that require only minimal, temporary disturbance to the FHA that can be totally restored (e.g. fully buried submarine pipeline).	As for 'A' management level. Other limited-impact public and private structures that are assessed as having an overriding requirement to be on tidal land or within the FHA (e.g. private jetty, erosion protection).

CONCLUSIONS AND FUTURE DIRECTIONS

It is clear from the data presented in this paper that the FHA network is affording statutory protection from development pressures to substantial areas of coastal and estuarine fish habitats. The network has focused on the east coast, where the highest development pressure is located, and has achieved an extensive, comprehensive and representative coverage of the available estuarine and coastal habitat types.

Historically, there has been less priority placed on FHA declarations in the West Cape York and Gulf of Carpentaria regions. This is not because these habitats are any less important to sustaining Queensland's fish stocks and fisheries. On the contrary, a number of highly productive and valuable fisheries (e.g. the inshore barramundi and the northern prawn fishery) are directly dependent on the quality and extent of the coastal and estuarine fish habitats in this region. The lack of focus on these regions has simply been a factor of the region's considerably lower adjacent development pressure. In recent years three FHA declaration projects have commenced in the Cape York region as an attempt to improve protection of the fish habitats in this region and further strengthen the FHA network. The acceptance of these proposals, particularly by the local indigenous communities, will significantly influence the future development of the FHA network in the West Cape York and Gulf of Carpentaria regions.

The FHA network between Cooktown and the New South Wales border is approaching a level of coverage that, from the perspective of fish habitat management, provides the basis upon which to divide the coast into two broad categories:

- Where appropriate development may be supported (outside FHAs), and
- Where development should be avoided (inside FHAs).

Such a broad categorization provides a clear framework for fish habitat protection and for coastal development and allows for its incorporation into adjacent terrestrial planning processes. While FHA management is effective in controlling development impacts within each declared Area, complementary terrestrial management is essential to ensure that catchment-generated impacts do not affect the fish-habitat values of the FHA network.

All legislation is a permanent reflection of the communities' collective view. With the increasing emphasis on government accountability in recent times, processes have been developed to ensure that legislation is regularly reviewed and therefore remains relevant to and reflective of community values. This is an important consideration when attempting to strategically plan the ultimate extent of the FHA network. The Queensland community retains a strong interest in fish, fishing and fisheries sustainability, which is reflected in the current level of community support for the FHA program. However, the further extension of the FHA network in some sections of the east coast requires careful planning to ensure that it allows for the communities' requirement for orderly, regional growth and prosperity. Should community support for the FHA network diminish as a result of over-declaration of the FHA network, the risk of a downgrading of FHA management across the entire network through legislative changes is a very real possibility.

The ongoing success of any aquatic protected area network must be measured and reviewed against its specific objectives. If the FHA network were to be assessed on its protection of coral reef habitats or across-shelf biodiversity, it would not rate highly. However, when assessed against its objective of protecting coastal and estuarine fish habitats from impacts of coastal development, the FHA network's focus on areas with the highest development pressure and its strong, statutory management indicate that it is successfully meeting this objective.

Further work on evaluation of the network is required, particularly with regard to determining:

- The economic and social value of the FHA network;
- The habitat types and their distribution within the network;
- Whether the declaration of additional FHAs in coastal regions unlikely to be the subject of significant coastal development pressure in the foreseeable future (e.g. the Gulf of Carpentaria) is an effective use of limited management resources; and
- The benefits of extending the FHA network into freshwater habitats.

Significant changes in the management of marine waters adjacent to the Queensland coast are under consideration (e.g. Rezoning of the Great Barrier Reef Marine Park and declaration of additional State Marine Parks). These proposed changes are for the purpose of marine biodiversity conservation and may overlay part of the FHA network. It is possible that, as a result of these initiatives, some sections of the existing FHA network might be closed to resource extraction including fishing. Any such changes would need to be fully justified and should only occur after robust debate by the community and all stakeholders. Strong support from Queensland commercial and recreational fishing sectors has been fundamental to the instigation and ongoing development of the FHA network. Coastal development has led to substantial loss of, and impact on, the natural capital (fish habitats, fish stocks) on which the industry depends. Increased restrictions of access, through spatial closures to remaining fish habitats, is likely to see restructure of the fishing industry. Unless any proposed spatial closures to resource extraction could be demonstrated to result in compensatory spillover and larval export to the fishery (Ward *et al.* 2001), it appears probable that marked changes in catches and seafood availability would result.

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USER FEES AT BUNAKEN MARINE PARK, INDONESIA: LESSONS IN DEVELOPING TOURISM-RELATED FINANCING MECHANISMS FOR MARINE PROTECTED AREAS

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Abstract

Marine protected areas (MPAs) around the world lack adequate funding to fulfill their basic mandate, biodiversity conservation, as well as additional goals such as fisheries management and the provision of tourism settings. Tourism's ability to bring additional funding to MPAs through fees and related revenue-generation mechanisms may be part of the solution; however, fulfilling this promise is not an easy process. This paper briefly summarizes what individual countries and marine protected areas are doing to generate revenue through tourism's presence in MPAs; data from more than 40 countries are presented. The challenges associated with establishing and increasing fee systems in MPAs are examined through a case study of Bunaken Marine Park in Indonesia; the role of stakeholders, participatory processes and the development of revenue-management mechanisms such as a conservation trust fund are described.

Keywords: marine protected area, financing, user fees, Indonesia, tourism

INTRODUCTION

The chief mandate of marine protected areas (MPAs), protected areas in or adjacent to coastal waters, is conservation of marine and coastal biodiversity. Their ability to achieve this goal, especially in developing countries, is severally curtailed by a lack of funding. A report by the World Wildlife Fund (WCPA 2000) states that most MPAs are "under-resourced and poorly managed, offering little in the way of real protection. Global estimates suggest that as many as 70–80% of the MPAs that have been established worldwide are protected in name only and are not actively managed at all." Many believe that tourism could be one of the answers to the funding problems of certain marine protected areas, but little data has been collected to support or disprove this.

MPAs are popular destinations for both local and international tourists; significant impacts arise from this visitation (Walpole and Goodwin 2000; Cater and Cater 2001; Halpenny 2002b; Kenchington 1992). Negative socio-cultural and environmental impacts have been well studied; however, less research has been devoted to understanding the potential positive benefits of tourism's presence in MPAs.

Some tools for generating revenue in MPAs have been identified (e.g. user fees, souvenir sales), but insufficient data have been documented on the success of these tools and the challenges associated with their implementation (van Sickle and Eagles 1998; Eagles 2000; WCPA 2000; Anonymous 2001; Lindberg 2001). This paper briefly summarizes a study designed to explore this issue on a global scale. The study details the success and failures of tourism-related revenue generation efforts for MPAs in more than 40 countries (approximately 30 surveys were returned from MPA practitioners). Information was collected from park managers, conservation NGO staff and community representatives via the Internet, as well as published materials. The study documents fees charged at individual parks and within national park systems as well as how the fee was administered and collected. Park managers were also asked to describe how the fee revenue was managed (i.e. did it go to a central treasury or was it earmarked for the park or an independent conservation trust), what kind of advanced notification of the fee implementation or increase was given to citizens and tour operators, was there any opposition to the fee and why, and whether the fee reduced visitation to the park or business for local tour operators. General findings are briefly described below, but further details can be found in Lindberg and Halpenny (2001a, 2001b).

GENERAL FINDINGS

There was great variation in the fees charged by MPAs. World renowned sites such as the

Galapagos (US$100/visit[1]) and Tubbatah in the Philippines ($50/visit) charged the highest fees. The most common fees were US$1 to $5 per day or $10 to $30 per year. It was also common to have a combination of fees charged, for example an entry fee to the park as well as a fee to dive or to moor a vessel. Sources of fee revenues included entrance fees, admission to enter an exhibit or building (e.g. a slide show or aquarium), rental fees (e.g. snorkel equipment), user fees (e.g. camp grounds), concession fees (e.g. stores and pontoon sites), licenses and permits (e.g. fishing and mooring), and special services (e.g. guided tours).

In general, the fees set by MPAs were rarely based on systematic research such as evaluation of fees charged elsewhere, financial needs of the marine park, or willingness-to-pay surveys of visitors. Rather, they were commonly based on anecdotal knowledge or the selection of an arbitrary amount.

Collection of fees generally took two forms. The first was payment at an official entrance to the park or at a popular snorkel or camping site within the park, with the issue of a paper ticket or dive tag to be worn on a diver's buoyancy-control vest. Alternatively, fees were paid in advance to a tour operator, travel agent or dive guide; these companies pre-purchased tickets in bulk from the management agency. Payment mechanisms were dependent on several considerations including the safety of park staff (i.e. the dangers associated with handing large sums of income on islands in the park far from police or enforcement protection), the type of fee charged (e.g. daily *v.* annual), the pattern of visitor activity (did visitors congregate at a few locations or enter at one point, or was visitor activity dispersed), and the ability to enforce payments.

Fees generally varied with activity and the nationality of the visitor. In most developing country parks, local or national visitors were charged less than international visitors. Snorkelers sometimes paid less than divers. Adding to the challenge of revenue collection and customer satisfaction was the impact of the management of different parks by different management agencies within the same region or country – each park would have different pricing policies. Visitors would have to pay several times and in different ways to different agencies. An effort to consolidate or at least simplify payment mechanisms for park visitors was being discussed in a couple of countries that were surveyed.

Management of fee revenues generally took one of two forms. Traditionally the fees would go to a central treasury. In theory, these revenues would be returned to the park system, but this is not always the case. More commonly, many MPAs have specific conservation trusts set up to manage the revenue accumulated through park fees (e.g. Belize's Protected Area Conservation Trust, see Halpenny 2002a). These trust funds are often managed by local stakeholders including the tourism industry, community members, government agencies, park managers and scientists, etc. The funds direct money to the management of the park on the basis of priorities set by the stakeholders.

This conclusion is based on Anecdotal information from park managers suggests that few fee increases have resulted in significant changes in park visitation. Exceptions were reported from the Seychelles and Egypt where close substitute sites were available to visitors and operators – offering them a free alternative with similar traits to the marine park site. In some cases, park managers reported an increase in visitation (Bonaire Marine Park and Bunaken National Park) as visitors equated fee payment with well managed coastal environments and coral reefs. In general (as with terrestrial sites), the willingness of visitors to pay for the marine experience (i.e. diving, snorkeling) generally exceeds the fees that are being charged.

However, implementation of fees should be made with caution because increases can affect local tour and dive operators (Lindberg and Aylward 1999). For example, a doubling of fees for a marine park might result in a 20% decrease in visits to the park but also an increase in overall revenue for the park. However, operators who are affected by a 20% decrease in visits might suffer significantly depending on the source of their business. In addition local residents may be more sensitive to price change than foreign tourists; this could be linked to local peoples' lower incomes, and their greater awareness of alternative sites (Lindberg and Aylward 1999). Implementation of fees in increments is recommended, with monitoring of impacts.

Opposition to fees generally originated from local residents and tour operators. Park managers report that the main reason for the opposition from tour operators was a lack of advance notice of the fee, and their inability to factor the fee increase into their package pricing. A 12–18 month advance notification is recommended by this study. In general, tour operators were supportive of fee increases if the revenue was retained locally for the management of the park. Education and the distribution of information on the reason for the fee introduction or increase were cited as the most powerful tools for gaining fee acceptance.

[1] All fees are listed in US dollars.

BUNAKEN NATIONAL PARK, INDONESIA: CASE STUDY

Bunaken National Park, established in 1991 on the northern tip of the Indonesian province of Sulawesi, has rich biodiversity, including extensive mangrove forests and coral reefs. For years it suffered from a lack of funding resulting in weak management and enforcement of protection laws; dynamite and cyanide fishing threatened reefs, and illegal forestry endangered mangroves. Several groups have worked together to establish a fee for visitors to the park. Local dive operators were very supportive of the initiative; they were involved from the inception of the project, working with park managers, international conservation agencies and Indonesia-based NGOs.

There are three general groups of visitors, divers, backpackers and local day-visitors. A survey determined that visitors would pay an entrance fee of at least $12.50. However, the sample for the survey was made up largely of backpackers, a budget-conscious group, and it is speculated that if the survey sample had focused more on the 10,000 dive tourists who visit each year the result would have been higher, perhaps $20.

For a majority of respondents to the survey their chief concern was the management of the collected fee. Visitors wanted to see the revenue go towards conservation programs in the park, rather than into the coffers of the government or the pockets of local officials. To address this issue, a pilot project was proposed for Bunaken; the government was lobbied for the creation of a more decentralized approach to fees management. The dive industry was a key ally in lobbying the government to pass the law that would change how the fee revenue would be distributed. The Bunaken National Park Management Advisory Board (a multi-stakeholder board consisting of representatives from the dive industry, environmental NGOs, academia, villagers from within the park, and government officials) was created, and receives 80% of the fee revenue, while 20% is split between national, provincial, and two district governments.

The fee was developed over a 10-month period, and came into effect in March 2001. Indonesian visitors pay a fee of Rp. 2,500 (US$0.30) and foreign visitors (divers, snorkelers, backpackers) pay Rp. 75,000 (US$8). Residents within the park are exempted. The managers and Board chose to introduce a relatively low fee for the first year for several reasons: (*a*) to minimize opposition from industry and especially from backpackers, (*b*) to prevent government officials from "eyeing" the funds collected as a treasure trove to delve into, and (*c*) to "prove" to tourists that their fees are really doing something before asking a larger fee – by starting small, they could avoid overly high expectations from tourists. The managers and Board estimate that it will require approximately $250,000 per year at a minimum to manage the park; given current estimates of approximately 10,000 visitors this would mean an eventual fee increase to $25/year. The system is based on that at Bonaire Marine Park: upon payment of the fee at one of two entrance gates within the park, or to a dive operator or travel agent (who buys passes in bulk from the Bunaken National Park Management Advisory Board), the visitor receives a waterproof entrance tag which must be worn. As in Bonaire, the tag has become a collector's item. Indonesian day visitors receive paper tickets, as with other national parks.

The implementation of the fees has gone very well. Divers and dive operators are very supportive. Some opposition has been expressed by travel agents who sell a small number of tours to park visitors. Their chief concern was that they were not consulted from the beginning and were not informed about the fee before their rate lists were published for 2001, thus they could not adjust their prices accordingly. Travel agents are now actively involved in the process, helping the Board to decide how to spend the revenue. The other group that remains in opposition is price-conscious backpackers. Despite an active campaign to inform travelers regarding the need for the fee and how it will be used for conservation within the park, backpackers remain unsupportive about the fee.

Another group whose involvement is increasingly sought is local villagers. Once the fee program was launched they became more and more concerned about where all the money was going. An extensive "socialization" campaign was implemented to let locals know just how the revenue was being used. Other educational campaigns include the development of a frequently-asked-questions sheet about the entrance fee and where the fees are going, and press releases and packages to numerous local newspapers, travel guides (e.g. Lonely Planet), and Asia-based diver and travel magazines; an announcement was sent out to all the wholesale dive operators worldwide who take tours to Bunaken, and large neon signs were placed in the arrival halls of the airport (M Erdmann, *pers.comm.*; Lindberg and Halpenny 2001).

To date, the implementation of the fee at Bunaken National Park has been a success, embraced. Careful tracking of visitor numbers, revenues and expenditures of revenue based on stakeholder guidance continues to be implemented. Recent terrorism attacks (e.g. in New York in 2001 and Bali in 2002) and the outbreak of SARS in the Asia region in 2003 have affected tourism worldwide and hence have made it difficult to track the actual impact of the new fee on visitor numbers. However, the positive impacts associated with increased enforcement of park boundaries and waste-management efforts appear to have reinforced the support from industry, government and community members for the fee program (M Erdmann, *pers.comm.).*

CONCLUSION

On the basis of literature previously published on the subject of park fees, and more specifically observations from park managers, NGO staff and community representatives surveyed for this study, several key elements are deemed essential for successful implementation of a fee program in marine protected areas.

- Education and public awareness programs are essential in ensuring the support of stakeholders (including visitors)
- Tour operators must be involved in the introduction /revision of park fees at the earliest stage possible, and must be given sufficient notice (i.e. 12–18 months) of fee changes.
- Differential fees (e.g. higher fees for foreign visitors than for national/local visitors) are useful and widely accepted where they have been implemented. They are an important tool for addressing issues of social equity, especially in developing countries.
- Conservation trusts, designed in part to manage revenue from fees, are becoming increasingly important in many countries and play an important role in ensuring that fee revenue is spent at the park site, or at least within the park system. Their success is contingent upon the transparent management of funds and participatory decision making.
- In several countries, collection of park fees by operators such as hotels and transport suppliers appears to be more cost effective than having park staff collect the fees at designated gates. In several countries, operators were given a 10% discount for buying tickets in bulk and then reselling them to clients.

This is by no means a complete list of elements essential for the successful implementation of fee programs at MPAs. Much more research is needed on this subject. Case studies, especially those that systematically document the implementation and effect of fees over time for specific sites and park systems, will be especially useful in understanding the elements that lead to effective, efficient and equitable visitor fee systems for marine protected areas.

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PUBLIC PARTICIPATION IN NEW ZEALAND: THE EFFECTIVENESS OF MARINE RESERVE ADVISORY COMMITTEES

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Abstract

Public participation and support are often cited as key elements for successful protection and conservation of natural areas. Aquatic protected areas are no exception to the principle of participation. There is much discussion about the need to include members of the community in management of protected areas; however, thorough examinations of the participatory process are needed to advance practice. The aim of this paper is to examine the effectiveness of New Zealand marine reserve advisory committees in incorporating principles of participatory theory. Four case studies are used to analyse the factors affecting community involvement. Perspectives of both reserve managers and advisory-committee members are included to provide perspectives of the participatory process. Interviews and questionnaires were the means used to gather information from those involved in marine reserve management. Seven elements found to influence committee effectiveness were (*1*) guidance and support, (*2*) membership, (*3*) meetings, (*4*) terminology, (*5*) finances, (*6*) results and (*7*) networking. The recommendations are compared with the Marine Reserves Bill 2002, to determine which issues are addressed by the new legislation and which issues need consideration in the future. The participatory process, its successes and failures, needs to be monitored if advances are to be made in effective community involvement. This research provides one more step in understanding the needs of community members and managers in their participation in the consideration of protected areas.

Keywords: advisory committee, marine reserve, New Zealand, participation, stakeholders

INTRODUCTION

Participatory approaches are being used with increasing frequency. A wide variety of approaches are 'participatory,' ranging from public consultation to community-based management (Arnstein 1969; Chambers 1994; Michener 1998). Participation, however, is not a clear-cut process. Problems can arise when participatory techniques are applied; these may be due to the following: inexperience; government desire to retain control; the time, money and effort needed; misconceptions of terminology; and a hesitation to involve the public early in the process (Howard *et al.* 1984; Bens 1994; Healey 1997; Venter and Breen 1998; Sandersen and Koester 2000; Roberts and Hawkins 2001). Despite the difficulties, facilitating community participation in planning and management can increase the effectiveness of aquatic protected areas (Fiske 1992; Barchard and Hilderbrand 1993; Gilman 1997; Nicholls 1998). To contain the scope of the paper, only one level of participation, advisory groups, is examined in detail.

Few studies have examined the effectiveness of aquatic protected area (APA) advisory groups as a participatory mechanism (Morin 2001; Uunila 2002a; Uunila in press). Therefore, much of the research is still exploratory. This paper reports a case study of four New Zealand marine-reserve advisory committees (MRCs) and discusses several elements that appear to contribute to an effective participation process.

ADVISORY GROUPS

Many nations facilitate advisory-group participation in APA management, such as Australia, France, the USA and New Zealand. Advisory groups are often established by government agencies to allow more meaningful participation than that facilitated by public consultation (Beuttler 1995; Ellsworth 1995). Arnstein (1969) equates advisory groups to a form of placation, a tokenistic practice. This does not mean that advisory groups cannot be valuable tools that allow community input (Innes 1998); however, caution is needed so that managers do not believe advisory groups are the most comprehensive technique to facilitate participation. The advisory nature of advisory committees is their greatest weakness. In a study of four United States National Marine Sanctuary Advisory Councils (SACs), Morin (2001) concludes that SACs are a useful means to

Table 1. Types of marine reserve advisory committee (MRC) in New Zealand Prior to Marine Reserves Act 2002 (Adapted from in Uunila in press.)

	ADVISORY	BOARD COMMITTEE	COMBINED	*AD HOC*
LEGISLATION	Conservation Act section 56	Conservation Act section 6N(2)(b)	Conservation Act section 56 and 6N(2)(b)	None
POWER	Advisory body to the Minister	Powers may be delegated by Conservation Board	Advisory body and delegated powers	No statutory power
WEAKNESS	Does not allow for management planning or policy advice	Must act within mandate of Conservation Board	Operates under two different sections of legislation	No statutory power
STRENGTH	Relationship with Minister (via Regional Conservator)	Policy advice and planning role	Advantages of both advisory and committee	Easiest committee to set-up
IN PRACTICE[i]	None	1) Te Whanganui-A-Hei and 2) Long Island-Kokomohua	1) Kapiti, 2) Te Angiangi, 3) Te Tapuwae o Rongokako and 4) Pohatu	Tuhua (Mayor Island)

[i]There is also one Conservation Board committee (not a MRC) that advises on all marine issues in the Northland Conservancy, including Poor Knights Islands Marine Reserve (DOC 2000).

facilitate public participation; however, a lack of management decision-making authority can lead to frustration amongst SAC members.

NEW ZEALAND MARINE RESERVE COMMITTEES

In New Zealand, no-take marine reserves play a significant role in the management of aquatic areas. At the time of the study, the Marine Reserves Act 1971 was the key piece of legislation. Soon after completion of this research, the Marine Reserves Bill (MRB) 2002 was introduced to parliament in June 2002. The MRB 2002 is intended to replace the 1971 Act; the new Act is expected to come into effect in the second half of 2002. It should be noted that the following descriptions relate to the 1971 Act.

The Department of Conservation (DOC) is responsible for the management of marine reserves, though mechanisms exist to facilitate public input into this management process. Public consultation is required during marine reserve establishment and statutory plan formation. Currently, tangata whenua[1], interest groups and the public can have some degree of management input through Conservation Boards and MRCs. Conservation Boards are independent statutory bodies comprising members of the public that advise DOC. Boards consist of 12 members, and there is one Board for each of the 13 Conservancies and one for the Chatham Islands. In contrast, MRCs are local mechanisms that allow community input into the management of specific marine reserves. Of the 16 marine reserves in New Zealand, eight have advisory committees (Table 1).

[1] First people of the land

Four types of MRCs were recognised at the time of this study: statutory advisory, Conservation Board committee, combined and *ad hoc* (DOC n.d.; Table 1). Reserves without a MRC fall under the scope of the applicable Conservation Board. Under the Marine Reserves Act 1971, there is no legislation to create MRCs; the Conservation Act is used instead[2].

METHODS

Cross-site analysis is used to examine New Zealand MRCs as an effective means of participation. Four case-study committees, Kapiti, Te Whanganui-A-Hei, Long Island-Kokomohua and Te Tapuwae o Rongokako, were selected by expert sampling based on informed opinion, through an interview at the national level of DOC. Three data-collection techniques were used: document analysis, semi-structured face-to-face interviews and surveys. Minutes, correspondence, plans, applications and other relevant material were examined. In addition, seven DOC Area Office staff members were interviewed and MRC members were asked to complete a postal survey. Response rates for the survey ranged from 55.6% (n = 5) for Te Tapuwae o Rongokako MRC to 62.5% (n = 5) [3] for Kapiti and 75% (n = 6) for both Te Whanganui-A-Hei and Long Island-Kokomohua MRCs.

[2] Under the MRB 2002, MRCs can be created which are either advisory or Conservation Board MRCs. Also included, is the ability to create management bodies, allowing a group, authority or person, other than DOC, to manage marine reserves.

[3] The percentages differ, though the number of responses is the same, because Te Tapuwae o Rongokako has a nine member MRC while Kapiti has an eight member MRC.

Table 2. Advisory Group Checklist for marine reserve advisory committees (Source: Uunila 2002a, p.125.)

STRENGTHS/WEAKNESSES	CHECK	MRC CHARACTERISTICS
Community contact with government officials	✔	Community, through tangata whenua and interest group representatives, work with DOC staff
Informs government of community view	✔	MRC members share their views with DOC staff
Government accountability	✔	MRC serves as a 'checks and balances' system
General public not usually involved in group	✔	Elite stakeholder groups, with the exception of Te Whanganui-A-Hei which is a modified elite group
Government controls finances	✔	DOC retains control of finances[I]
Low meeting frequency	✔	Case study mean of 1.98 MRC meetings per annum
Group has little/no decision-making power/ responsibility	✔	Conservation management plan approval only true power allocated to MRCs
Volunteer burnout	Possible	Volunteer burnout in Long Island-Kokomohua – could be a reason for poor attendance
Little contact with local authorities	✔	Contact with local authorities usually in the form of letters or submissions; little direct contact

[I] Te Whanganui-A-Hei MRC has a $1000 Board budget; member remuneration may be paid with this money.

Table 3. Four marine reserve advisory committees investigate in the present case study. (Adapted from Uunila 2002a and in press.)

	KAPITI	TE WHANGANUI-A-HEI	LONG ISLAND-KOKOMOHUA	TE TAPUWAE O RONGOKAKO
Marine Reserve	2167 hectare reserve 30 km north of Wellington, protects a portion of the waters around Kapiti Island – established in 1992	840 hectare reserve on the Coromandel Peninsula – established in 1992	619 hectare reserve protects the waters around Long and Kokomohua Islands in Marlborough Sounds – established in 1993	2450 hectare reserve north of Gisborne – established in 1999
Committee Est.	1993	1993	1993	2000
Members[i]	Eight: iwi (4), non-iwi interests (4)	Eight: iwi (4), local community board (1), community interests (3) [also includes an ex-officio member who is a member of the Conservation Board]	Eight: iwi (3), Conservation Board (2 – one of whom is tangata whenua), Combined Dive Clubs (2), Picton Fishermen's Association (1)	Nine: iwi (5), Commercial Fishers Association (1), Tatapouri Sports Fishing Club (1), Royal Forest and Bird Society (1), Conservation Board (1)
Powers	Management plan approval and ability to create a working party	Management plan approval	Advisory nature only	Management plan approval and ability to create a working party
Weakness	The marine reserve is the target for organised poaching; historically the MRC has focussed on this problem with few tangible results	Established as a committee of the Conservation Board, the MRC had little official direction until terms of reference were created in 2000	Quorum at only 50% of MRC meetings	Because of its recent establishment, the MRC has not developed to its full potential
Success	Rserve management plan approved (1998); Area Office hired a contract public awareness officer who worked with MRC	Strong interpretive programme, includes an education kit, a snorkel trail and interpretation kiosk; Ngati Hei (tangata whenua) are involved in compliance and law enforcement activities	MRC is heavily involved in research application recommendations and monitoring research projects	The first marine reserve jointly proposed by tangata whenua (Ngati Konohi) and DOC; MRC invited the adjacent landowner to have input into policy

[i]Membership breakdown is from the MRCs' terms of reference; Kapiti and Te Whanganui-A-Hei MRCs both include a scientist from the National Institute for Water and Atmospheric Research amongst their members.

FINDINGS AND DISCUSSION

An advisory group checklist has been devised (Table 2), comprising findings from international case studies and advisory-group characteristics. Comparison of New Zealand MRCs with this list indicates that MRCs are classic examples of advisory groups. All the positive elements of advisory groups are mirrored in MRCs; unfortunately, many of the weaknesses are also present. Each MRC deals with situational issues; there are differences among MRCs, including membership, structure and focus. Table 3 outlines each of the four case-study MRCs. No national MRC guidelines exist to direct practice, though a draft discussion document was composed in the 1990s (DOC n.d.). Detailed examination of individual cases is beyond the scope of this paper; however, seven contributing elements to MRC effectiveness arose in each case study: (*1*) guidance and support; (*2*) membership and representation; (*3*) meeting attendance and frequency; (*4*) misconceptions of process; (*5*) finances; (*6*) tangible results and (*7*) networking.

Element 1: Guidance and support. MRCs are dependent on their Conservation Board, DOC Area Office and terms of reference. In some situations, there is a cooperative environment, with all parties working together; in others, there is poor communication between the Board and MRC, limiting the effectiveness of the committee.

DOC Area Offices provide logistical support including meeting venues and secretarial assistance. DOC staff who work with MRCs can assist the committees by supporting MRC decisions and advocating them within higher levels of the Department. Innovation is also vital. For example, the Waikanae Area Office hired a contract public-awareness officer; half her time was allocated to the MRC. Whether it is DOC staff or MRC members who innovate, support of these ideas is key to success. At the Aquatic Protected Areas Congress 2002, the need for staff dedication[4] and continuity (Sheppard this volume 2003) were emphasised. In the open comments of the MRC survey, these sentiments are echoed, because several respondents credit MRC success to the dedication of DOC staff.

In each of the case-study MRCs, the Conservation Boards also have a role to play. The Board provides terms of reference for the MRC[5]. In Long Island-Kokomohua Marine Reserve, the Board and MRC negotiated the terms of reference. In the other three cases, the terms of reference were given to the MRC. Te Whanganui-A-Hei, though operating since 1993, did not have terms of reference until 2000. The MRC members had requested guidance as to their roles and several reviews of the MRC were conducted, questioning its functionality. However, the terms of reference were only created when the Board believed the MRC had overstepped its bounds.

The Conservation Board can also support MRC decisions, endorse them and advocate them to the Conservancy level of DOC. Kapiti, Te Whanganui-A-Hei and Long Island-Kokomohua MRCs have all had requests supported and/or investigated by their Boards. Te Tapuwae o Rongokako MRC, however, does not have a relationship with its Board. One survey respondent stated, “we don’t even know who the Board members are”.

The Conservation Board also has a role in membership. Kapiti is the only MRC that does not have a member of the Board sitting in on MRC meetings. However, a MRC member has been made an *exofficio* member of the Board to create that link. Te Tapuwae o Rongokako has a Board representative; however, the representative has attended only one of four meetings, diminishing the ability to communicate between the two bodies.

The support and guidance of theDOC and Conservation Board assist MRCs in attaining their goals. Therefore, roles for all three bodies should be clearly outlined. Terms of reference should also be negotiated amongst all parties concerned.

Element 2: Membership and representation. Advisory groups are termed a “small-group approach” by Howard *et al.* (1984, p. 37). Exactly who is represented by this small group is a decision that can facilitate or hinder the process of participation. Groups and communities are not homogeneous (Agrawal and Gibson 1999; Slocum *et al.* 1995), making stakeholder selection difficult. Causey (this volume 2003), emphasised the need to ensure that members are “stakeholder leaders” who are respected by the people they represent. Sandersen and Koester (2000) believe the only people who can decide whether membership is representative are the users. However, government still often selects advisory group members (Neuman 1999; Morin 2001).

Donaldson (1994), in an Environment Canada publication, outlines three types of stakeholder groups: those created from existing groups; elite models, in which specific stakeholders representing special interest groups are requested to participate; and new groups – in which anyone, including the public, is allowed to participate. Other means of describing groups define stakeholders themselves (Table 4). Wilson and

[4] L. Sterling, Theme 3 presentation, 15 August.

[5] In the case of combined MRCs, there may be a second terms of reference created by DOC

Table 4. Stakeholders of marine reserve advisory committees

(Source: Uunila 2002, p. 27; material from: Borrini-Feyerabend 1996; Howard et al. 1984; Mitchell 1997)	
PRIMARY	**SECONDARY**
Have a connection to the issue or area; often have a greater role in decisions and management	Have a less immediate connection to issue or area
ACTIVE	**INACTIVE**
Members of the public belonging to interest groups	Members of the 'general' public; often do not want to become involved, leaving their views underrepresented
REPRESENTATIONAL	**DIRECT**
A deliberative effort by managers to achieve a broad cross-section of individuals who represent different needs and interests; can be both active and inactive public	Open participation, everyone has the opportunity to have input during all phases; a broad spectrum of representation is not sought by managers

McCay (1998) believe it unlikely that inactive members of the public would desire a place on an advisory group, meaning that it is often interest groups that are represented in advisory committees. Exclusion of the public from marine advisory groups is a recognised practice (Ellsworth *et al.* 1997). In three of Morin's (2001) SAC case studies, this deficiency is rectified through one or more citizen-at-large council positions. The inclusion of government officials in advisory group membership can increase government accountability to the group (Beuttler 1995).

The four MRCs in this case study use *primary*, *active* and *representational* stakeholders selected through a nomination process by either the Conservation Board or Area/Conservancy Level of DOC, with final approval coming from DOC. Classification of the case studies according to Donaldson's (1994) committee types reveals that three committees are *elite*. Te Whanganui-A-Hei MRC is the exception, as three stakeholders do not represent tangata whenua or specific interest groups. Therefore, this committee falls between Donaldson's (1994) *elite* and *new* categories. The DOC staff interviewed believe that MRCs are representative of *primary* and *active* stakeholders, whereas the majority of MRC survey respondents believe the MRCs to be representative of the public. In practice, participation is limited to tangata whenua/interest group participation (Table 3); except in the case of Te Whanganui-A-Hei. The inactive public can attend MRC meetings and address the MRC.

The MRCs have developed good working relationships with DOC; however, the interviews and surveys did not produce any solid affirmation of communication between tangata whenua/interest groups and their MRC representatives. To ensure better representation and communication with the public and groups, several steps can be taken. The level of information exchange between MRC members, the iwi[6] and groups represented and the public needs to be researched; once that is complete, communication mechanisms can be created.

Two MRC respondents noted concern over lobby-group representation – an environmental group in the case of Te Tapuwae o Rongokako MRC, and a recreational group in the case of Long Island-Kokomohua MRC. This issue has not been noted in other examinations of APA advisory groups; however, previous research conducted for DOC reveals that a perception exists amongst tangata whenua that some lobby groups, specifically environmental and recreational groups, have a better relationship with DOC than iwi have – despite specific requirements under the Treaty of Waitangi for good iwi/Crown relations (Centre for Research 1998). The Marine Reserves Bill 2002 recognises the need to give effect to the Treaty of Waitangi and include tangata whenua in MRCs. To alleviate problems regarding member selection, a transparent process should be created, including a written statement why each candidate is selected for participation.

Element 3: Meeting attendance and frequency. The literature on APA advisory committees does not address meeting attendance. However, the frequency of meetings receives attention from Beuttler (1995), who suggests that in France, the Scandola Marine Reserve Advisory Committee, which meets one to two times a year, would benefit from meetings that are more frequent. A greater frequency would mean that issues could be dealt with in a timely manner (Beuttler 1995).

Meeting frequency (mean) amongst the four case studies ranges from 1.7 to 2.2 per year (Table 5).

[6] Tribe

Table 5. MRC Meetings per year

MARINE RESERVE COMMITTEE	1993	1994	1995	1996	1997	1998	1999	2000	2001 [i]	Total	Mean	Median	Mode
Kapiti	3	3	1	1	1	1	1	2	2	15	1.7	1	1
Te Whanganui-A-Hei	1	3	2	2	4	2	2	2	2	20	2.2	2	2
Long Island-Kokomohua	5	2	2	1	2	1	4	0	1	18	2	2	1 and 2
Te Tapuwae o Rongokako	-	-	-	-	-	-	-	3	1	4	2	2	1 and 3

Source: Uunila 2002b, p. 10.
[i] Data collection ends: 8/01 Kapiti, 9/01 Hahei, 12/01 Long Island, 4/02 Te Tapuwae o Rongokako.

Table 6. Absenteeism and Attendance in MRC Case Studies (Source: Uunila 2002b, p. 11.)

MRC	ABSENTEEISM	ATTENDANCE RATE
Kapiti	Minutes do not indicate the groups represented by MRC members; examination of non-attendance is not possible.	86%
Te Whanganui-A-Hei	Minutes do not indicate the groups represented by MRC members; examination of non-attendance is not possible	66% [i]
Long Island-Kokomohua	All representatives have been absent at least once; commercial fishing representative and tangata whenua (from one to all four representatives) have the highest rates of non-attendance	60%
Te Tapuwae o Rongokako	Recreational fishing and Conservation Board representatives have been absent for three of four meetings[ii]	76%

[i] Based on a total of nine, percentage from figures that count the ex-officio Conservation Board member.
[ii] Notably, the Board states in its annual report that it "*wished to retain an active interest and overview role in relation to Committee work and have found that this is best served through a nominated Board member maintaining a membership role*" (East Coast Hawke's Bay Conservation Board 2000, p. 11).

This level corresponds to that of the Scandola Marine Reserve Advisory Group described by Beuttler (1995). Moreover, MRC meetings per annum have ranged in the past from no meetings to five. If the MRC cannot address issues in a timely manner, its effectiveness as an advisory body is reduced, making the committee more a token of participation than an effective mechanism. Efforts should be made to ensure at least two MRC meetings per annum.

Meeting attendance is a significant issue (Table 6). Reasons for non-attendance cited by MRC respondents include ill health, other commitments and absence of new agenda items. Non-attendance may also be influenced by one or more factors revealed through data analysis, including frustration with the system and lack of the following: feedback; remuneration; benefits; capacity building, concrete objectives and tangible results.

Absenteeism can limit the ability of MRCs to act through lack of a quorum. Long Island-Kokomohua MRC, for example, only has a 50% rate of quorum achievement. If one group is continually absent, then different problems arise. In the case of Te Tapuwae o Rongokako MRC, the recreational fisher representative, like that of the Conservation Board, has attended only the first of four MRC meetings. This means that DOC staff and MRC members cannot begin to understand the perspectives held by the local fishers through the MRC forum, nor can they ensure that the views of the fishers are represented in policy. A stepped-plan should be created to deal with persistent absenteeism, including possible replacement of the MRC member or the creation of alternative means of communication.

Element 4: Misconceptions of the process. Clarification of the participation process involves clarification of terminology, roles and expectations. Walters and Butler (1995) state that a problem exists with the misapplication of terms by conservation agencies. Because there is no consistent use of terminology, false expectations can be created and misunderstandings can occur (Uunila 2002a).

MRCs are advisory and are most often described as such in literature. However, in some instances DOC uses the term partnership, even when there is no sharing of power or responsibility. Prior to the Marine Reserves Bill 2002, the only possible structure for MRCs has been as an advisory body. However, amongst MRC respondents, some changes are desired, especially as regards to funding and resource allocation. If MRC members desire increased input into management, who should decide if the members have adequate capacity? DOC is responsible, under legislation, for marine reserve management; therefore, DOC has the power to decide. If a checklist of community participation levels within the advisory-committee context were to be developed, then those MRCs that statisfied the requirements for one category could move up to the next, if they so desired. A framework is presented in Table 7, which could allow more meaningful participation and encourage capacity building. Although such changes may not be possible under current legislation, this concept requires further examination to assist in the creation of a more effective advisory group process. Applying Table 7 to the MRCs in the case study reveals that Long Island-Kokomohua and Te Tapuwae o Rongokako MRCs are clearly Level I committees. Kapiti, because the MRC uses outside experts on some issues and aids DOC in prioritising activities, is a Level II committee. Te Whanganui-A-Hei does not fit into any one of the first three levels but demonstrates elements of each; its low

Table 7. Advisory Committee Levels and Checklist (Source: Uunila 2002a, p. 140.)

LEVEL	DESCRIPTION	RESOURCES	CHECKLIST TO MOVE UP TO THE NEXT LEVEL
I	Basic advisory body, providing input to DOC. Government retains control of finances, responsibility and power.	Information provided by DOC[i] Funds held and managed by DOC	✔ At least one meeting per annum ✔ 65% attendance rate ✔ Members want more input
II	Advisory body, with greater input into allocation of funds. Government retains control of finances, power and responsibility.	DOC provides majority of information; outside experts used when required Funds held and managed by DOC, MRC aids in prioritisation of activities	✔ At least one meeting per annum ✔ 70% attendance rate ✔ Use of outside experts when required ✔ Members want more input
III	Advisory body, with input into allocation of funds, and control over a small budget (e.g. $NZ1000). MRC responsible for allocated budget.	DOC provides majority of information; outside experts used when required Funds held by DOC; MRC responsible for expenditures from allocated budget	✔ At least two meetings per annum ✔ 75% attendance rate ✔ Use of outside experts when required ✔ Members want more input and fund control
IV	Advisory body, but capacity building of MRC members is a new focus. MRC responsible for a medium-sized budget (e.g. $NZ5000).	DOC provides majority of information; outside experts used when required Funds held by DOC; MRC responsible for expenditures from allocated budget	✔ At least three meetings per annum ✔ 80% attendance rate ✔ Use of outside experts when required ✔ Capacity-building and skill-training initiatives sought for MRC members ✔ Members want more input, control of funds and responsibility
V	Advisory body paired with a 'Friends of Marine Reserve' group. MRC provides input to DOC and retains control over its DOC budget (e.g. $NZ5000). Using 'Friends of' status, MRC seeks grants and sponsorship, using the money in the reserve as it sees fit; consulting with DOC.	Information provided by DOC and outside experts Marine reserve funds managed by DOC. MRC responsible for expenditures from allocated budget MRC controls monies raised by the 'Friends of' organisation	✔ At least three meetings per annum ✔ 80% attendance rate ✔ Use of outside experts ✔ Capacity-building and skill-training initiatives sought for MRC members ✔ Members want more input, fund control and responsibility → consider co-management options

[i] In all five levels, members also contribute expertise and local, traditional and scientific knowledge.

attendance rate and non-use of outside experts mean that it cannot achieve Level II or III status. However, Te Whanganui-A-Hei does have a small budget allocated by its Board; this is discussed further in the finances section below.

Element 5: Finances. Financing of advisory groups is a significant issue, especially in times of fiscal restraint. Finances available to MRCs both for projects and for member remuneration are examined. Kriwoken (1991) suggests that an improvement to the Great Barrier Reef Consultative Committee would be committee control of finances. A DOC Area Office investigation reveals that MRCs cannot have *direct* access to a bank account (Te Whanganui-A-Hei MRC 1999). However, in 2000, Te Whanganui-A-Hei MRC was allocated $NZ1000 by its Conservation Board. This money is held by the DOC Area Office and is used at the discretion of the MRC; a year-end financial summary must be presented to the Board. MRC member remuneration, once provided by the Board,[7] is included in this amount. Direct control of funds means that a MRC can act as it sees fit, increasing the "capacity and power to be an effective organisation" (Uunila 2002b, p. 13).

MRC member remuneration is not consistent. Statutory advisory and combined MRC members must be paid (DOC n.d.); hence, Kapiti and Te Tapuwae o Rongokako MRC members are paid. However, only the Conservation Board members who sit on a Board MRC must be remunerated (Teoh 1994). As stated above, Te Whanganui-A-Hei, a Conservation Board MRC, currently has money that it can allocate to remuneration and/or projects. In Long Island-Kokomohua, another Conservation Board MRC, there is inequity, because the two Board members are remunerated[8] but the six other members are not. Remuneration is one means to acknowledge the value of participants' time and effort. There should be consistent and equitable remuneration amongst all MRCs.

Element 6: Tangible results. Tangible results increase participant enthusiasm and support (Barchard and Hilderbrand 1993; Ellsworth 1995). Kapiti and Te Whanganui-A-Hei MRC both have tangible results from their efforts, namely a conservation management plan; Te Whanganui-A-Hei has also produced an information kiosk, a snorkel trail and interpretation panels. MRC survey respondents from both these reserves indicate 100% support for maintenance of the present MRC system. Long Island-Kokomohua MRC is lacking the small victories that result from tangible goals; this is possibly one reason why the MRC has not succeeded in having many meetings with a quorum. Te Tapuwae o Rongokako MRC has aided in developing an Operational Plan and brochure; since the reserve is relatively new, it is not expected there will be many visual reflections of MRC efforts. Survey respondents from the latter two MRCs indicate 60% support for maintenance of the present MRC system; there may be other influencing factors, but tangible results are a recognised means of maintaining volunteer interest and support. Therefore, APA managers should encourage the creation of attainable objectives that demonstrate to participants that they are making a difference.

Element 7: Networking. Networking is needed to link individuals, all of whom have their own 'reality' or perceptions (Healey 1999). "[B]elonging to a network, or making informal links with other like-minded people, can significantly strengthen the position of those who are thus inspired and enabled to work for change" (Eade 1997, p. 146). Networking serves to increase people's capacity to act (Eade 1997).

Networking occurs within MRCs through the joining together of diverse members, DOC staff and, in some instances, Conservation Boards. Networking among MRCs is not as successful. At various periods since inception, Kapiti, Te Whanganui-A-Hei and Long Island-Kokomohua MRCs have been involved in exchanges of information and Minutes (Uunila 2002a); Te Tapuwae o Rongokako began too recently to have participated in the networking as yet. Networking is not a system-wide practice, nor is it a constant. There is no policy on sharing successes and failures, and this results in efforts that are at times redundant. Uunila (2002a, 2002b) suggests four options for networking and sharing between MRCs: (*1*) exchange of meeting Minutes or summaries; (*2*) annual report and/or newsletter mail-outs; (*3*) central database of marine reserve management topics; and (*4*) central resource collection. Networking and sharing can provide several benefits, including reducing duplication of efforts, allowing others to learn from mistakes, providing inspiration for action, and allowing selection of initiatives that fit the local context (Uunila 2002b).

[7] After requesting a report on MRC member remuneration, the Waikato Conservation Board decided to pay the Te Whanganui-A-Hei MRC, though the Board encouraged those MRC members with means not to take remuneration (Stephenson 2000).

[8] The two Board members receive remuneration because they are paid for attendance at Board meetings which are held on the same day as MRC meetings (K. Walls, pers. com. 16 August 2002).

Table 8. Recommendations from the present study that have been addressed by the Marine Reserves Bill 2002

RECOMMENDATIONS	MARINE RESERVES BILL 2002
Guidance and Support	
Roles clearly outlined	MRB outlines MRC functions and powers (clause 26)
Terms of reference negotiated	Not addressed in MRB, flexible details should be negotiated on an individual MRC basis
Membership and Representation	
Research on degrees of communication; communication mechanisms created	Recommendation not relevant to legislation, can involve informal surveys (e.g. phone calls to groups represented) or formal research
Transparent stakeholder selection process (e.g. written justification for each candidate)	MRB outlines general membership structure (clause 27), members to include: tangata whenua, local community, other persons/representatives with interests in the reserve, Conservation Board member. Need for transparency not addressed
Meeting Attendance and Frequency	
Plan for persistent absenteeism	The Minister may add members (clause 29a) or revoke appointments (29b)
Ensuring *at least* two meetings per annum	One annual meeting necessary, others can be convened [Schedule 1 4(2) and (3)]
Misconceptions of Process	
Clearly defined terms	Not addressed in MRB
Early dialogue regarding roles and powers	Timing not addressed; MRB outlines MRC functions and powers (clause 26)
Finances	
Creation of MRC budget	No separate budget for MRCs
Consistent and equitable remuneration	Remuneration decided by Minister [Schedule 1 (22)]
Tangible Results	
Clear, attainable objectives	Not addressed in MRB
Networking	
Shared resource collection	Not addressed in MRB
Communication network	Not addressed in MRB, but addressed regarding DOC staff in draft national strategy 'Building Support for Marine Protection;' calls for networking amongst staff, annual workshops and conferences (DOC 2002) – no reason MRC members cannot be involved

FUTURE DIRECTIONS AND CONCLUSIONS

The Marine Reserves Bill 2002 addresses recognised deficiencies in the Marine Reserves Act 1971. Table 8 demonstrates how the MRB, as presented to parliament in June 2002, addresses issues raised in this paper; not all seven elements are addressed; some elements are more relevant to strategies than to legislation.

The four MRCs in this case study demonstrate the potential of the advisory committee concept, and provide examples of the caution needed when implementing such a participatory strategy. MRCs provide a medium through which members of the public and DOC staff can share ideas and opinions, and can devise strategies. The MRCs are only as effective as the environment in which they exist – this includes members, supportive organisations, policies and established direction. There is a need for professionalism on the part of all participants, so that the full powers of the advisory format can be brought to fruition and not be hindered by issues such as absenteeism. Working together, participants must develop a process that works for the protected area, the management authority, the advisory group and the community.

This research is preliminary. Further research is needed in many areas, including studies to determine correlations between the elements, perceptions of committee effectiveness, satisfaction with the process and willingness to participate. Ideally, research into the social aspects of participation will be encouraged, because there is a need for more published examples of advisory group practice.

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DEVELOPMENT, OUTCOMES AND FUTURE OF AN AREA CLOSURE IMPLEMENTED BY THE INDIGENOUS COMMUNITIES OF NORTHERN CAPE YORK

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Abstract

Aggregations of the sciaenid *Protonibea diacanthus* form annually in the inshore waters of northern Cape York (Queensland), and have been exploited by indigenous subsistence fishers for more than 50 years. The management of aquatic resources used by indigenous fishers is a relatively new concept to many natural-resource management agencies in Australia, and presents many unique opportunities and obligations. Participatory stock assessment of *P. diacanthus* in the Northern Peninsula Area (NPA) revealed that sexually mature fish constituted less than 1% of the subsistence harvests in 1999 and 2000. The findings indicate a rapid change in the fish stock, and warrant concern for the state of the resource given that the fishery was previously based on mature adult fish. In response, the traditional land owner groups of the NPA in September 2000 imposed a two-year ban on the harvest of *P. diacanthus*. With consultation, this initiative has developed into a regional agreement, with comprehensive support across all communities of the NPA and the adjacent Torres Strait Islands. The area of closure incorporates the inshore waters of the NPA north of Crab Island (on the west coast) and Albany Island (on the east coast). The aim of this community-developed management response is to allow local stocks of *P. diacanthus* to reach a mature size so that prospects for replenishment are improved.

Keywords: aboriginal, Torres Strait Islander, subsistence fishing, Protonibea diacanthus, Cape York

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INTRODUCTION

In times past, the Aboriginal owners of Cape York monitored their land and sea country to prevent the act of trespass and unsanctioned use of resources. Today in the Northern Peninsula Area (NPA), the use of aquatic resources by persons outside the traditional owner groups is commonplace. However, the traditional owners of the region continue to express a strong desire to maintain their obligations to protect their customary sea estates and ensure the sustainable use of the resources.

The collaborative management of aquatic areas used by indigenous fishers is a relatively new concept to many natural resource management agencies in Australia. This paper presents an example of the successful outcomes that can be achieved through cross-cultural appreciation of management priorities and processes. This will review the development, outcomes and future of a community-developed area closure that stemmed from a participatory research study.

BACKGROUND

This case study focuses on the management outcomes of an ongoing project that commenced in 1997 and has resulted in five years of close involvement with the Injinoo Aboriginal Community. Injinoo is close to the northernmost point of the Australian continent (see Fig. 1). The community lies more than 1000 km from the nearest city (Cairns), though there are a number of small indigenous communities nearby. The communities of Umagico, New Mapoon, Bamaga and Seisia are also within the NPA (north of the 12th parallel of latitude).

The community was founded almost 100 hundred years ago when the remnants of the clans whose customary lands occupy the northernmost 200 km of Cape York came together on their own accord in an effort to escape the recent incursion of European settlers. The establishment of the community brought together five traditional owner groups: the Anggamuthi, Atambaya, Gudang, Wuthathi and Yadhaigana. The population of Injinoo is presently less than 400 people, while the greater population of the NPA is now more than 2500 people. More than 95% of the population in the region are of Aboriginal or Torres Strait Islander descent.

The research that preceded the area closure focused on aggregations of Australia's largest tropical sciaenid, the black jewfish *Protonibea diacanthus* (Fig. 2). These fish reportedly attain sizes of up to 180 cm in length and 45 kg in weight and are highly regarded by fishers. Aggregations of *P. diacanthus* form annually in the inshore waters of the NPA, and have also been reported at northern Australian locations extending from Central Queensland (Bowtell 1995) to northern Western Australia (Newman 1995).

Aggregations of fish, be they formed for the purpose of feeding, spawning or migrations, are vulnerable fishery targets (Johannes *et al.* 1999; Turnbull and Samoilys 1997). The largest member of the family Sciaenidae, *Totoaba macdonaldi,* is an example of this. *T. macdonaldi* is considered to be critically endangered and is now listed on the IUCN Red List of Threatened Animals, a consequence of overfishing during the annual spawning-aggregation period (True *et al.* 1997).

In the northern peninsular region of Cape York *P. diacanthus* is quantitatively one of the most important components of a diverse subsistence fishery in which some 75 marine and freshwater taxa and a range of harvesting methods are used by the indigenous people of Injinoo (Phelan 2002b).

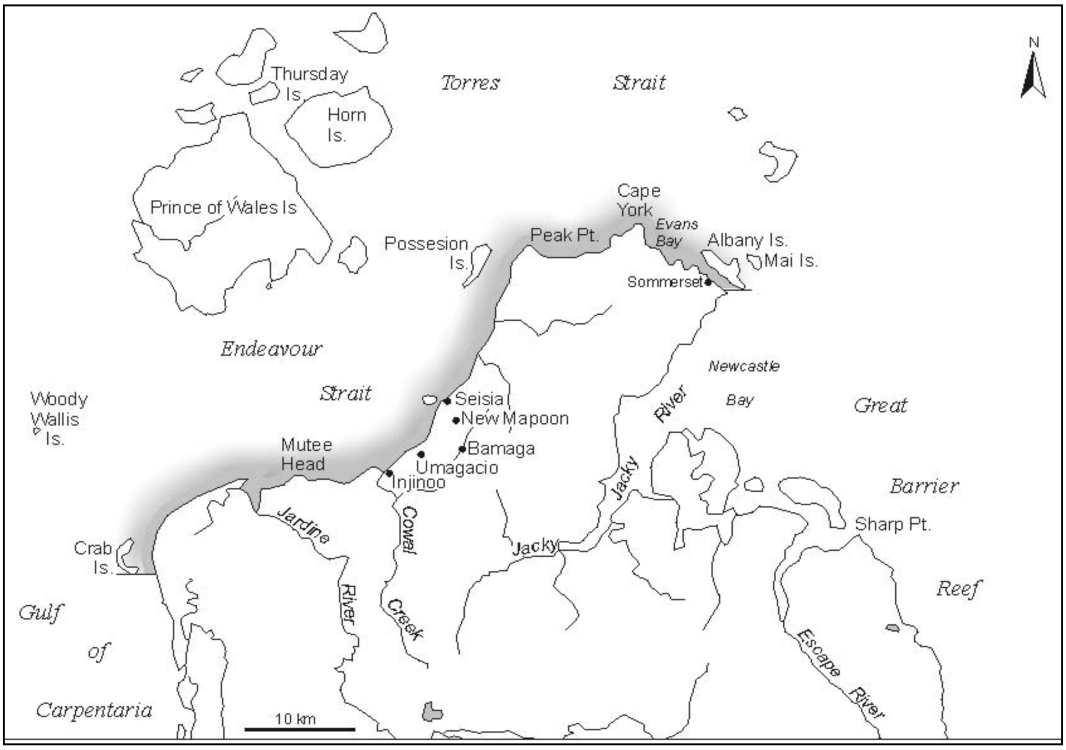


Fig. 1. Area within the Northern Peninsula Area closed to the harvest of *P. diacanthus* under the regional agreement.

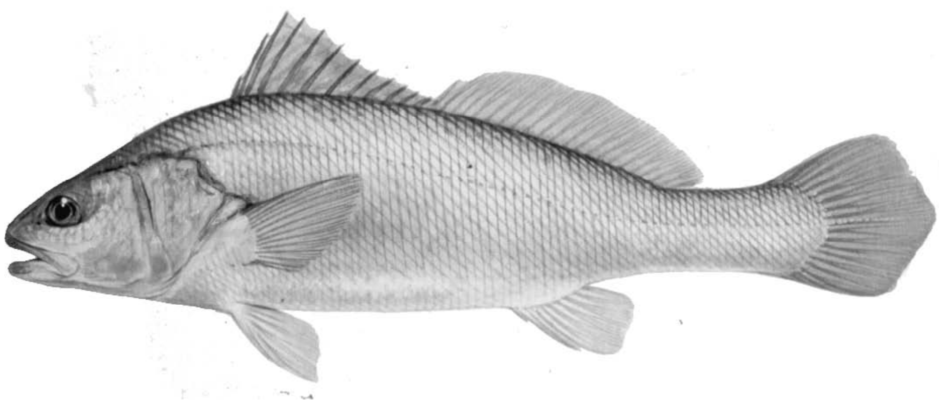


Fig. 2. Adult *Protonibea diacanthus*.

In order to set the context for this case study, I begin this paper by demonstrating the growing importance of enhancing the involvement of indigenous stakeholders in the management of aquatic areas. I proceed by introducing the need for the research before moving onto the key methods and findings. I follow this with a discussion of the subsequent management outcomes, and conclude by outlining the future of the area closure.

The growing importance of the indigenous subsistence-fishery sector

One-third of Australia's indigenous people live within 20 km of the coastline (Australian Bureau of Statistics 2001). Many of the coastal clans of Australia's Aboriginal nations identify as 'saltwater people', and their traditional estates typically extend beyond the coastal zone and into the seas. In general, these coastal people view the sea as a cultural landscape, an extension of, but no different from, land, with similar inherent responsibilities (Tanna 1996).

In Australia, recognition of the importance of 'land' to Aboriginal cultures is a relatively new concept. It is only ten years since the Australian High Court decision that acknowledged the native title rights of indigenous Australians (*Mabo v. Queensland, 1992*). The legal validity of Aboriginal 'sea estates' is even more recent, having been recognised only within the past three years (*Mary Yarmirr & Others v. the Northern Territory of Australia and Others, 1999*).

Following these High Court decisions, the inherent rights and responsibilities of indigenous people under customary law are now recognised under Australia's common law. As a consequence, the rights of indigenous peoples to their traditional marine resources, and their role in the management of their customary estates, are of increasing relevance to the administration of coastal and marine resources in Australia.

In all, there are about 100 coastal communities, mostly in northern Australia, occupying land under some form of Aboriginal or Islander leasehold or title (Smyth 1993). Indigenous members of these communities in northern Australia are largely exempt from federal and State legislation with regard to the use of marine resources when these are harvested for the purpose of traditional or subsistence use.

Although indigenous people represent less than 2% of Australia's population, this figure is nonetheless growing rapidly. In the past decade, there has been a 45% increase in the number of people who identify themselves as an indigenous Australian (Australian Bureau of Statistics 2002). There are many reasons behind this dramatic increase, a major contributor being a birth rate greater than the national average. Exemplifying this, at Injinoo 49% of the population is less than 18 years old.

It follows, then, that in the immediate future there is the potential for a rapid increase in fishing pressure on local resources. This appears more evident when one also factors in the improving economic situation among many of Australia's indigenous communities. At Injinoo, for example, there were five powered vessels in the community in 1990, and ten years later the number had increased to 42; at the same time there were 48 houses in the community. By comparison, in 1999 it was estimated that only 11% of all Queensland households owned a boat used for personal fishing (Roy Morgan Research 1999).

That the level of boat ownership far exceeds the State average reflects the continuing importance the indigenous community places upon fishing and hunting. This notion is exemplified in the high participation rate in activities that use aquatic resources. In recent surveys, 95% of households at Injinoo stated that they had participated in such activities within the past twelve months (*v.* 32.8% of all Queensland households), and of these 81% fished at least weekly (cf. 7% of recreational fishers) (Phelan 2002b; Roy Morgan Research 1999).

Need for the present project

The research study was initiated in response to concerns among the area's traditional owners regarding the impact of the perceived increase in fishing activity targeting the aggregations of *P. diacanthus*. The annual aggregations that form off Muttee Head, ~15 km south-west of Injinoo, have been linefished by indigenous subsistence fishers for more than 50 years. *P. diacanthus* are also used in the NPA by local and transient recreational fishers, and by tourist anglers from all over Australia and the world.

An extensive body of evidence derived from fish stocks around the world indicates that target fishing of aggregations can rapidly undermine sustainable fishery production. Chronic effects of aggregation fishing include the truncation of size and age structure (e.g. Beets and Friedlander 1992), deterioration of the stock's reproductive capacity (e.g. Elkland *et al.* 2000), and altered genetic composition (e.g. Smith *et al.* 1991). Acute effects include the total loss of aggregations (e.g. Sadovy 1994).

Exemplifying the vulnerability of this species, the once-flourishing commercial fishery along the north-west coast of India has recently been described as 'non-existent' (James 1992). Anecdotal evidence suggests that intensive fishing has also severely affected several annual aggregations of *P. diacanthus* along the east coast of Queensland (Bowtell 1994, 1998). Yet, despite this, there has remained a dearth of information on the species and the demands made upon those stocks by the various fishery sectors. In particular, the biological purpose and importance of these aggregations had yet to be demonstrated.

METHODS

Following raised awareness of the concerns held by the traditional owners of the NPA, Balkanu Cape York Development Corporation (an indigenous organisation representing the people of Cape York), approached the Queensland Department of Primary Industries' Northern Fisheries Centre. Together they successfully obtained funding from the Fisheries Research Development Corporation (FRDC). This was the first time that this Corporation had funded research principally devoted to examining an indigenous fishery.

Prior to the commencement of sampling, we met the community residents and promoting a two-way discussion of the needs of the project. From feedback generated at later stages, this initial consultation was deemed critical to the success of the project. Although seemingly unproductive in terms of annotated results, this period was essential to identifying the issues of concern to ensure the relevance of the research, and to ensure the transmission of salient objectives so that the direction of the project was clear to all.

The residence of the project biologist within the community for the most part of the study's duration greatly benefited the project. Injinoo Community, like many other Australian indigenous communities, is the focus of numerous studies each year. Researchers in almost all these studies 'fly-in and fly-out', with the community often gaining little understanding of the study and its findings. However, to reside in the community for such an extended period of time required considerable support, given the limited community resources such as accommodation and office facilities.

As far as possible, community members were involved in the design and implementation of the project, as well as the interpretation of results. The continued involvement of local fishers was integral to the success of the project. Not only did they provide the critical information on the spatial and temporal scales of the fishery, they also assisted greatly in providing biological samples. Limited paid employment opportunities were provided within the project, but most of the participation was voluntary. In order to maintain the high level of community ownership of the project, the community was consulted throughout all stages, with the results being released in a transparent manner, acceptable to the various stakeholder groups, as soon as they became final.

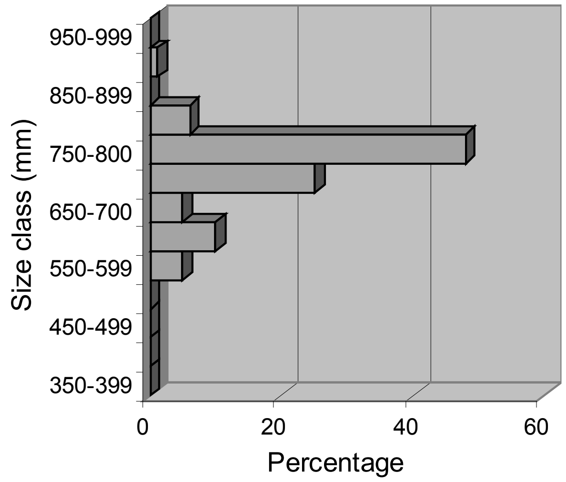
RESULTS

The lack of existing catch data on the fishery was overcome by collating the oral accounts of traditional owners and long-term residents. These provided a record of the fishery since its inception, and presented evidence of changes in the demographics of the fishery, the harvest levels and stock condition. Very detailed information was available from members of the community; for example, elders were able to recall the first indigenous person who caught a representative of the species and the year in which this happened. The indigenous fishers held a fine understanding of the spatial and temporal attributes of the aggregating behaviour of the fish stock. The seasonal, lunar and tidal patterns had long been common knowledge among fishers, but have hereto remained undocumented.

Knowledge of the aggregating behaviour of the fish appears to have facilitated the increased harvest of the species. Most of the recorded catch in 1999 (3.9 tonnes) and 2000 (4.5 tonnes) occurred during the aggregation conditions described by fishers. In contrast to their normal behaviour, these fish are exceptionally easy to harvest when aggregating. Catches of *P. diacanthus* typically exceeded 50 fish per boat, with catches of over 100 fish per boat not uncommon. Recorded CPUE ranged up to 250 kg per hour/boat.

Data from more than 4000 fish observed in the catch revealed a decline in the average size of the fish within the two years of monitoring (Fig. 3); in 1999 the fishery was dominated by fish in the size range 75–80 cm, whereas in 2000 the dominant size class had decreased to 60–65 cm. Oral records reveal that specimens close to the maximum size (>150 cm) were caught until 1994. An alternative method of visualising this change is to view the age structure of the harvested fish stock (Fig. 4). In 1999 the fishery was dominated by fish believed to be three years old, whereas in 2000 the harvest was dominated by fish believed to be two years old.

In the two years of the study, sexually mature fish constituted less than 1% of the catch examined in a sampling program biased towards the largest individuals available. This is quite concerning given that estimates of the critical stock threshold for tropical fish range between 20% and 40% (Turnbull and Samoilys 1997). Among the fish showing evidence of sexual maturity, the development of the gonads coincided with the aggregation season. However, no hydrated or



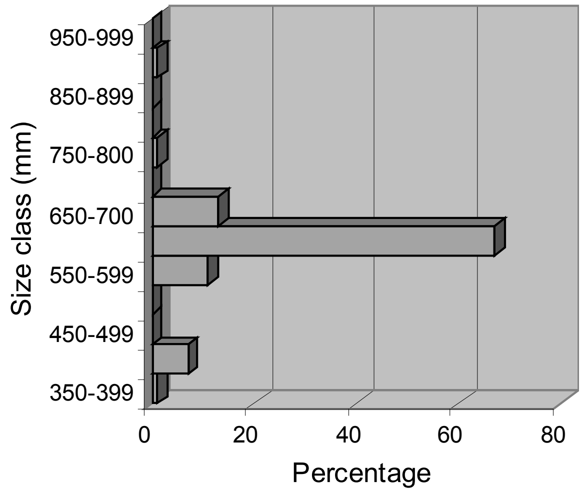


Fig. 3. Composition of the size classes of *P. diacanthus* harvested off Muttee Head in (*left*) 1999 and (*right*) 2000.

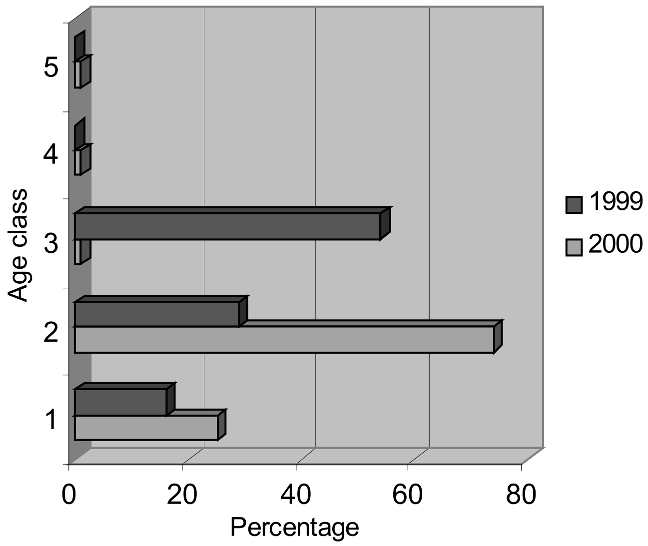


Fig. 4. Composition of the age classes of *P. diacanthus* harvested from the Northern Peninsula Area Head in 1999 and 2000.

spent gonads were observed, so the exact timing and location of spawning could not be confirmed. Yet the indigenous people of the Injinoo do eat the eggs of many marine species and state that ripe eggs of *P. diacanthus* were readily available during previous aggregations when larger fish where abundant.

Also of concern was a decrease in the age of the first maturity observed among female *P. diacanthus*. From the adjacent waters of the Gulf of Carpentaria, first maturity in females occurs at four years of age (McPherson 1997). Four-year-old fish were not present in the 1999 catch, and amongst the three year olds no evidence of sexual development was observed in that year. However, in the following year, even though the proportion of the three-year-old stock was greatly reduced, some of these displayed evidence of sexual maturity. Whether this was an artefact of increased sampling, or a direct consequence of the sustained fishing pressure, is the subject of further investigation.

Food items observed in the analysis of the diet of the fish (n = 270) included teleosts and invertebrates. The range of animal taxa represented in the prey items supports the description of an 'opportunistic predator' attributed to the species by Rao (1963). The limited data gained in the project presented no evidence to support the notion that the seasonal migration of *P. diacanthus* was related to the increased availability of prey items in the inshore waters, as had been suggested by Thomas and Kunja (1981). Stomach contents during the midyear aggregation did not differ from those at other times of year.

The tag-and-release study (n = 114) provided limited data on the movement patterns of *P. diacanthus* in the NPA waters. Tag returns showed that some of the fish remain at, or return to, the aggregation site at least into the following day. The recaptures also revealed the movement of an individual fish between two distinct aggregation sites. This was supported by DNA fingerprinting (n = 109) using the Amplified Fragment Length Polymorphisms (AFLP) technique. No significant genetic variation was found amongst fish sampled from the adjacent aggregation sites. As several aggregation sites are fished in the NPA, their participation in multiple aggregations may increase their susceptibility to capture.

Management outcomes

The comprehensive consultation process maintained throughout the project ensured that the implications of these research findings were rapidly acted upon by the communities of the NPA. In response to the research findings, the Injinoo Elders and Land Trust, immediately requested their people to cease to harvest *P. diacanthus* for a period of two years. The area declared closed to the harvest of the species incorporates the inshore waters extending from Crab Island on the west coast to Albany Island on the east coast (Fig. 1). The area closure incorporates three well known aggregation sites and one migration corridor.

At the request of Injinoo Community, negotiations were conducted with neighbouring communities. Representing each of the communities of the NPA, the Umagico Aboriginal Community, Bamaga Islander Community, New Mapoon Aboriginal Community and Seisia Islander Community have undertaken to support the two-year ban on the harvest of the species. Further, Torres Shire and the Kaurareg Nation of the adjacent Torres Strait region are also signatories to this community initiative. Proprietors and operators of all tourist-accommodation and fishing-charter boats operating in the NPA region have also pledged their full cooperation.

With much public consultation, this community initiative developed into a regional agreement, with comprehensive support across all communities of the NPA and the adjacent Torres Strait Islands. This outcome was consolidated in September 2000 during a public meeting attended by a diverse subsection of the local communities. At that meeting there was unanimous support for the two-year ban, and it was decided that the management action should be initiated immediately.

Adding to the uniqueness of this self-imposed management arrangement, the elected Chairmen of these indigenous communities have formally requested legislative backing so that the Queensland Fishing and Boating Patrol would be able to enforce the management outcome over the two-year period. In order to achieve such, community members are prepared to forfeit their statutory exemption to the relevant catch restrictions for this species. The Queensland Fisheries Service recognises the importance of these public desires, and management responses are in progress.

So what does the future hold?

The aim of the two-year area closure is to allow *P. diacanthus* inhabiting the NPA waters to reach a mature size so that prospects for the replenishment of the fish stock are improved. Each of the parties involved recognises that the two-year period may not provide adequate time for the complete recovery of the proportion of the adults in the population. The parties concerned also recognise that even if there is a recovery in the short-term, unless exploitation levels are controlled in the future, there might be another decline in the fish stock.

Consequently all parties advocated a review of the stock condition prior to the end of the two-year period, so that an informed decision can be made on future management needs. An application for further funding to meet this public expectation was promptly fulfilled by the FRDC. The participatory approach to this project has matured to a stage where the task of collecting biological and fishery data is being organised and fulfilled by community members. Minimal training was required for this step as many local fishers were heavily involved in the initial research, and hence were familiar with the protocols required.

A local charter-boat operator is providing great assistance to this project by making available his vessel. Indigenous fishers are assisting on these dedicated trips and are conducting the necessary sample and data collection. Together with further reproductive and genetic samples, length-frequency data are being collected. Now that critical baseline information is available, the assessment of the size/age structure of the population provides an appropriate means to detect responses of the fish stock to given levels of fishing pressure. From the limited information received so far, it appears that *P. diacanthus* of at least four years of age now inhabits the waters of the NPA.

We are aware that some *P. diacanthus* have been harvested during the term of the closure. However, despite the lack of legislative backing, the total catch is a small fraction of former levels and the sustained pressure placed upon the stock has successfully been relieved. The future of the area closure is to be discussed further with the NPA and Torres Strait Community when the results of the stock assessment are completed. There remains a strong desire among the indigenous and non-indigenous community of the region to maintain local management input and decision-making. Certainly, the high community involvement should be recognised as highly beneficial to the acceptance of, and compliance with, the accepted management solutions.

CONCLUSION

The implementation of the community-developed two-year closure exceeded all expectations and provides a precedent for related projects. The outcomes appear unique among Australian fisheries, being the only example we know of in the modern context in which indigenous communities have initiated the long-term ban on the harvest of a fish species. The success of this outcome is believed to be a product of the community's understanding, participation and ownership of the research and management process.

This outcome demonstrates that, provided with the appropriate opportunities and information, mutually beneficial relationships may be developed between indigenous communities and resource managers. This ongoing partnership between the resource users and government agencies is critical; particularly in areas where surveillance and enforcement options are limited by distance. The remoteness of the majority of the Australian coastline increases the importance of the public's acceptance and ownership of management arrangements such as marine protected areas.

I thank Injinoo Aboriginal Community, Chris Roberts from Balkanu Cape York Development Corporation (who initiated this project), Rod Garrett and Neil Gribble from the Northern Fisheries Centre, Queensland Department of Primary Industries, and all those who have contributed to this project.

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MARINE PROTECTED AREAS GENERALLY REQUIRE EMPHASIS ON SPECIFIC OBJECTIVES FOR EFFICIENCY AND BROAD COMMUNITY ACCEPTABILITY

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Abstract

In Western Australia, marine protected areas established under legislation for marine parks or fish-habitat protection generally have broad objectives. These objectives include sustainable fish management, preservation of biodiversity, protection of ecosystems, provision of scientific reference sites and protection of sites for recreational viewing. These are legitimate objectives; but for any protected area the specific objectives to be served should be identified. Clear identification of objectives enables assessment of the success of the protected area and consideration of alternative methods for achieving those objectives. It is proposed that management of marine conservation should be approached on a regional basis using a variety of methods not restricted to protected areas. Traditional fishery management methods can be considered if the political, social and economic environment is suitable. Transparency of objectives and minimisation of social disruption in locating no-take areas will help in gaining community support.

Keywords*:* marine, reserves, management, fishing, recreational

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INTRODUCTION

This paper primarily considers marine protected areas from the perspective of a recreational fisher and conservationist in Western Australia, but it will endeavour to identify issues that are particular to that situation and consider differences that would arise in a different environment. Western Australia is fortunate, from a marine-conservation point of view, in having 27000 km of coast and a population of only 2 million people. Commercial human exploitation of marine resources has been occurring for less than 200 years. Thus, although some local degradation and depletions have occurred, conservation of natural ecosystems is a realistic objective.

This paper differentiates between different types of protection of marine areas. Protection from substantial habitat degradation will be described as habitat protection and areas in which there is protection of marine biota from predation by humans will be described as no-take areas.

THE WESTERN AUSTRALIAN MARINE PROTECTED AREA PROGRAM

Marine protected areas (MPAs) in Western Australia are established either under conservation and land-management legislation as Marine Nature Reserves or Marine Parks or under fisheries legislation as Fish Habitat Protection Areas. In both cases, zones or the whole area can be proclaimed as no-take areas (sanctuaries or marine nature reserves) or areas can be protected from nominated activities. Habitat protection is usually guaranteed, except for hydrocarbon exploration and production activities. In some cases the fully protected areas occupy only a small proportion of the reserve, most of which is open to commercial and recreational fishing. However, in Ningaloo Marine Park (Ningaloo Marine Park Management Plan 1989), there are a number of sanctuary zones of up to 50 sq km in area and about 25% of the lagoon and surface reef area is in sanctuary zones. In marine reserves currently being planned, sanctuary zones of up to 200 sq km are proposed. However, recreational fishing organisations have expressed concern over some proposals for no-take areas in parks currently under consideration and this has focussed attention on the rationale for such areas.

This paper supports the principles of marine conservation; but recommends that proper planning for MPAs should identify the reasons for no-take areas quite specifically. It is essential that the specific need be identified so that the adequacy of the no-take area can be assessed and its subsequent performance can be monitored. This paper examines this issue further and in doing so suggests a different system for marine conservation to that currently used in Western Australia.

Differences between conservation management of marine and terrestrial areas

There are undoubtedly many differences in management for conservation of marine and terrestrial areas but four are of particular significance to the argument of this paper:

- coastal areas below high water are in public ownership in Australia; in contrast, a large proportion of the land is held in private freehold ownership or in private long-term crown lease;
- coastal waters are managed by public agencies in Australia; the division of responsibilities between agencies may be according to particular areas vested in them, or it may be an overall responsibility for a particular function; land is generally managed by the private owner or leasee unless it is crown land reserved for a particular purpose and vested for that purpose;
- humans have evolved in a terrestrial environment and their exploitation of land has been much more intensive than marine exploitation; up to 90% of terrestrial areas have had their natural habitats completely changed by agricultural or urban development, and to stem the loss of biodiversity it is essential to preserve as much as possible of the little remaining original habitat; most of the marine area still retains a substantially unaltered habitat even though fishing may have greatly changed species abundance, trophic structure and other ecological relationships; and
- although birds and plants with wind-dispersed seeds travel freely over large distances, most terrestrial species are restricted by distance and by natural or man-made barriers such as roads or cleared land; in contrast, most marine organisms have remote-dispersal mechanisms (spores, eggs or planktonic larvae) which move freely with currents in an environment that has a considerable degree of uniformity.

It is suggested that these four differences should lead to differences between marine conservation management and the conservation management of terrestrial areas. It is necessary to establish a terrestrial park as a special area vested for conservation purposes to bring it under appropriate public management. On the other hand, all marine areas in Australia are publicly owned and can be managed appropriately for conservation within the limits of other agreed uses. The cadastral boundaries of terrestrial conservation reserves have real meaning because the surrounding land is usually under different ownership and management and has a vastly altered habitat. In contrast, marine reserve boundaries are much less distinct and the reserves and their surrounding areas clearly belong to a single system.

It does not seem logical to give almost the whole emphasis in marine conservation to reserves (protected areas), just because publicly owned reserves have to be the core of the conservation system on land. A sensible alternative is surely to manage the whole area of coastal seas in an appropriate way to achieve conservation objectives.

Conservation in marine parks versus overall marine conservation

Whether it is possible to manage the whole area of coastal seas to achieve conservation objectives will depend on the political and socio-economic circumstances of the host country. In order to try to manage the whole area properly, that country would require the following characteristics:

- effective government;
- adequate public scientific and financial resources;
- good communication between government and an educated population; and
- preferably the absence of a subsistence fishery – such a fishery puts almost unbearable social pressure on a management system and contains enormous latent effort if technology improves.

In some developing countries with a high population, many of whom depend on subsistence fishing, it is probably not practical to aim at overall management. In those circumstances the best interim solution may well be to concentrate limited resources on managing some fully protected marine areas. Such full protection would include no-take provisions as well as habitat protection. However, the above criteria do apply in Australia. In such circumstances it should be possible to apply an overall management system in Australia. This does not mean there should not be any no-take areas; but it is suggested that marine conservation should be an overall system, not just limited to marine parks.

Reasons for having protected marine areas

Managing fish resources for sustainability

Managing fish resources sustainably has been firmly established as an objective for a long time in Australia. The recent (Australian)

Commonwealth [federal] Guidelines for the Ecologically Sustainable Management of Fisheries (Environment Australia 2001) have given additional emphasis to this. The most common ways of managing commercial fisheries for sustainable yield are to limit catch directly by quotas or, as is more common in Western Australia, to limit effort. Bag and size limits plus a mix of other measures may be used to limit traditionally recreational catches. An alternative way that has been proposed for achieving sustainability in a fishery (Ballantine 1997) is by establishing a network of no-take areas.

It is difficult to carry out experimental studies comparing traditional fishery management to a network of no-take areas in terms of efficiency and efficacy. Most of the available information on the impact of marine area protection on fish catch comes from modelling studies. Roberts and Hawkins (2000) reviewed fifteen such studies. Those studies conclude that the proportion of the total area that needs to be protected for the highest sustainable production depends on many factors including fishing intensity, the characteristics of the fish species and the characteristics of the environment.

In any given situation, an estimate should be made of the efficacy and efficiency of management by traditional catch and effort restrictions compared with a network of no-take areas. The difficulties of doing this are recognised. However, in the absence of such an overt comparison, there is an argument about the need for MPAs without any basis for resolution. This may be further complicated by participation of members of the conservation lobby who hold other views. It has so far proved difficult to have rational scientific inquiry, using the best available evidence, into which management techniques are best for which situations in Western Australia. If the task is approached scientifically instead of emotionally, knowledge will gradually accumulate.

The conclusion is that there is no necessary requirement for no-take areas to manage fishing sustainably; but an informed decision needs to be made for any situation as to what fishery management system should be used.

Preservation of biodiversity

This is an overriding requirement for both terrestrial and marine management. However, threats to biodiversity in terms of extinctions are not common in marine environments (Davis *et al.* 1998). If there really is a threat of extinction to a marine species that can be prevented by a no-take reserve then an appropriate reserve should be established. Because specialisation in habitat requirement is a factor in extinction risk (Musick 1999), it is likely that habitat protection will be at least as important in preventing marine extinctions as no-take areas.

Ecosystem protection

Natural ecosystems can be disturbed by physical or chemical impacts on the marine environment or by fishing activities that cause major changes in abundance and thus affect trophic interactions between species. It can be argued that, as well as preserving biodiversity in terms of individual species, ecosystems should be protected from human interference to preserve natural interactions between species. This may preserve biological niches that reduce the risk of unexpected extinctions. To fully preserve ecosystem function, both habitat protection and no-take provisions may be required.

Snorkelling and dive viewing

Many people are interested in underwater swimming or diving to look at special marine environments, and the value of this experience is enhanced by the presence of charismatic marine fauna. Some of the most interesting fish are the large predators, which are very rare in easily accessible and heavily fished waters. No-take areas can provide appropriate sites for snorkel and dive viewing. Such sites do not have to be very large; published information from elsewhere (Roberts and Hawkins 1997) and Western Australian observations indicate that quite small areas of less than 100 hectares provide good viewing. On the other hand, these sites have to be in locations naturally frequented by fish and easily accessible from population centres or holiday resorts.

Scientific reference sites

Representative scientific reference sites are required if we are to make progress in our knowledge of marine management. Monitoring of such sites provides datum points with which we can compare the results of our management systems. Making long-term provision for monitoring must be an integral part of the establishment of these no-take areas.

A Procedure for Marine Management of a Coastal Region Including Protected Areas Based on Purpose

The above list of purposes for no-take areas is neither exhaustive nor unique but it does encompass most of the commonly identified reasons for MPA. It therefore provides a logical framework for examining the need for protected marine areas. This can be considered as a decision tree where the decisions are taken in the order set out below:

1. Has a threat of extinction been identified in the area? If so, can the threat be best countered by habitat protection, from trawling or industrial activity for example? If the answer is 'yes', a habitat protection area should be established. If the establishment of a no-take area can best counter the threat then a no-take area should be established.
2. Is there a demand for dive viewing sites because of eco-tourism activities, population centres, or coastal resorts? Are there suitable sites where high densities of interesting fish may be seen? If community consultation identifies such sites then appropriate small areas should be established as no-take areas for this purpose.
3. Has it been agreed between scientists that area protection is likely to be the most appropriate technique for managing all fishing in this region or a significant proportion of the targeted species? If so, then the agreed parts of the area should be protected from all fishing or particular kinds of fishing (if the area protection is temporary or for part of each year this would be regarded as conventional fishery management). The size and number of no-take areas will be influenced by the need to adequately buffer the area from fishing on the edges yet to have adequate migration of targeted fish from protected to fished areas.

   If area protection has been adopted as the fish management system for the region, then it is likely that the area fully protected for this purpose will be sufficient to meet the needs of ecosystem protection and scientific reference sites so the process is complete. If, however, the overall fish management system is to remain, as it is currently in Western Australia, a mixture of catch and effort limits with some spatial and temporal closures, then other steps are needed.
4. Areas should be set aside with habitat and no-take protection to meet the needs of ecosystem protection and scientific reference sites. Obviously, such areas must include representation of the range of habitats in the region. They should be fairly large to reduce edge-effect problems. These areas should be as far as possible away from areas of high human use to minimise social impact and therefore improve the likelihood of their implementation.

A DIFFERENT SYSTEM FOR MARINE CONSERVATION

The different system proposed for coastal marine conservation is to emphasise the importance of preserving, as far as possible, the ecology of the whole coastal marine area in a natural condition. This would change the management units from individual marine reserves to coastal regions. For Australia, the Interim Marine and Coastal Regionalisation for Australia (IMCRA Technical Group 1997) could be the basis. Within each region the decision framework discussed above could be followed. The major decision of whether to manage fishing sustainably by traditional methods or by a mosaic of protected areas would be one step in the process and would be made overtly. It is suggested that in Australia the default position is to manage fishing by the systems that are already in place. However, the alternative of a no-take network could be examined on a region-by-region basis. In some countries, where strong management systems are not in place and resources are limited, a network of no-take reserves may be the most practical system.

Even if traditional fishery management systems are usually adopted, there will be a need in most regions for no-take areas to preserve natural ecosystems and provide monitoring sites as discussed above. These should be located in such a way as not only to achieve their objectives but also to minimise social disruption. If such a system were to be adopted in Australia, there would be a need to convince the various government agencies to co-operate more closely than they do now and to provide cross authorisations and share resources for better efficiency.

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COMMUNITY ENGAGEMENT IN THE ESTABLISHMENT OF MARINE PROTECTED AREAS: AN AUSTRALIAN CASE STUDY

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Abstract

In June 2002 legislation was passed in the State of Victoria, Australia's second most populous state, to protect 5.3% of Victoria's marine estate in a system of IUCN Category II protected areas. The system was established in the context of broader provisions for the ecologically sustainable use of the entire marine environment. The legislation was the culmination of an 11-year policy process that involved extensive community engagement through the provision of information and opportunities for community participation. Initial evaluation of the policy process identifies three issues that will inform the continued evolution of national and international norms for community engagement in protected area management: the duration of policy processes, their scope and detail, and the establishment of a broad basis for community participation.

Keywords: community-engagement, policy, Marine Protected Area, establishment

INTRODUCTION

On 13 June 2002 the Parliament of the State of Victoria, Australia, passed legislation that established an aquatic protected area system covering 5.3% of Victoria's marine estate; within this system, all biota and habitat is protected. It consists of 13 discrete areas called marine national parks and 11 smaller discrete areas called marine sanctuaries. The level of protection is consistent with IUCN Category II protected area (IUCN 1994).

In many ways this event was without precedent and of world standing. The system protected 5.3% of waters in a single jurisdiction. Its design was ecosystem-based and it was established in the context of the ecologically sustainable use of the entire marine estate.

By Victorian and Australian standards, the event was also significant in public policy terms. It concluded a policy process of 11 years, involved extensive community participation in Australia's second most populous State, and saw bipartisan political support for laws that permanently established the protected area system.

This paper draws on selected elements of this policy process as they relate to marine protected areas. In an overview of the study area it provides a biophysical and sociopolitical setting for the case study. It then outlines aspects of the 11-year process, including community participation. The paper concludes by briefly highlighting implications that may be relevant for those involved in the establishment of marine protected areas and in planning initiatives for oceans.

THE CASE-STUDY AREA

Victoria's marine waters span 190 km of latitude from 37° to 39°S and 790 km of longitude from 141° to 150°E. They cover some 10,000 sq km and include open coastal waters within three nautical miles of the coastline and marine waters of Victoria's bays, inlets and estuaries. These waters are typically shallow, mostly less than 30 m deep, but in some localised areas reach depths of 100 m. Five bioregions have been mapped (Interim Marine and Coastal Regionalisation for Australia Technical Group 1998). Four bioregions cover Victoria's open coastal waters and one bioregion covers Victoria's bays, inlets and estuaries.

In 2001 Victoria's population was 4.8 million. In terms of marine industries, Victoria receives some 2500 ship visits each year with Victoria's largest port, Melbourne, annually handling some $A60 billion worth of trade and contributing in excess of $A5 billion to the economy a year. The first sale price of wild fish stocks, as landed in Victoria, is $A140 million with about a third of this value derived from the abalone fishery. Aquaculture production from these waters is in its infancy, but is expected to expand. Participation in recreational fishing is estimated at 225,000 persons for fresh and marine waters combined. Victoria also provides the operational base for a petroleum industry, with 2000/01 production valued at $A2.9 billion, that operates in marine waters adjacent to those of Victoria.

In general and simple terms, the Government for practical purposes assumes legal ownership of Victoria's marine estate, because only it can set rules or laws for access to these areas and the resources they contain. Government in Victoria consists of three structural components: administrative arm, executive government (Government) and parliamentary government (Parliament). Victoria's Parliamentary Government is based on a tripartite structure: the Crown represented by the Governor of Victoria and advised by the Executive Council, an Upper House and a Lower House being the seat of Executive Government. Victoria's bicameral system of checks and balances has fundamentally shaped the nature of Parliament in Victoria (Wright 1992) and requires that both Houses support legislation, such as the Bill to establish a system of marine national parks that is the subject of this case study.

THE CASE STUDY

The events that led to the establishment of the marine national park system spanned some 11 years (Table 1) and were part of a broader process that also examined questions related to the sustainable use of the marine environment. For the purposes of this paper we have concentrated on those events related to the park system. The process commenced in a conventional way in 1991, with the Victorian Government establishing terms of reference for an investigation.

Table 1. A timeline of selected steps in the establishment of marine national parks in Victoria between 1991 and 2003.

Sept. 1991	Reference requiring investigation of the use of Victoria's marine waters issued to the Land Conservation Council by Government. • June 1993 – Descriptive Report released for public comment • April 1995 – Proposed Recommendations released for public comment • June 1996 – Draft Final Recommendations released for public comment
Sept. 1997	New reference requiring the completion of the investigation issued to the Environment Conservation Council by Government. • February 1998 – Interim Report released[1] • December 1999 – Draft Report released for public comment • August 2000 – Final Recommendations provided to Government for its consideration
May 2001	Government announced its response to the Final Recommendations. Government introduced Bill to establish marine national parks. Government subsequently withdrew the Bill on 13 June, when it became obvious that the major opposition party would not support key provisions of the Bill.
March 2002	Government released a Proposal Paper that indicated its intention to introduce a revised Bill to create marine national parks. Government and Opposition announced agreement in principle.
April 2002	Government released draft Bill for public comment.
May 2002	Government introduced Bill to establish marine national parks.
June 2002	Victorian Parliament passed legislation on 13 June. Governor provided royal assent for the legislation on 18 June.
Nov 2002	System of marine national parks and marine sanctuaries established on 16 November.

[1]In December 1998 the responsible Minister requested the Environment Conservation Council to review aspects of the recommendations contained in the Interim Report.

The terms of reference related to the sustainable use of Victoria's marine estate and the protection of significant values. Implicit in these terms of reference was a focus on setting the long-term direction for the way in which Victoria's marine space would be allocated for various purposes. At that time, <0.05% of Victoria's marine estate was protected, at levels equivalent to IUCN protected-area management categories I, II or III (Hough 1996), and the application of the newly emerged concept of ecological sustainability was in its infancy.

The terms of reference were the initial responsibility of the Land Conservation Council, and subsequently of the Environment Conservation Council. These were statutory advisory bodies, and operated under legislation that outlined the processes for the conduct of investigations, especially in relation to community engagement and the assessment of the socio-economic implications of proposals. These bodies had no coercive powers to require the provision of information and no role in managing natural resources or marine space.

The style of operation of the councils can be traced to the late 1960s and the passage in 1970 of the Land Conservation Act (Borthwick 1970). Their operation was intended:

- to place the process of generating recommendations about the use of the public estate at arms length from Government;
- to make decisions about the allocation of Victoria's terrestrial and marine environments (often referred to as 'land') for particular uses by the orderly consideration of natural resource management issues, rather than by responding to parochial political matters; and
- to ensure community participation through an open and well advertised process.

For its day, this was ground-breaking legislation and was without precedent in Australia. It aimed to provide a politically bipartisan approach to allocation of land and to establishment of protected areas (Land Conservation Council 1988) that 32 years later, as outlined below, had important implications for the establishment of marine national parks.

Initial action on the terms of reference was taken in September 1991, when the Land Conservation Council, through public advertisement, media articles and letters to key organisations, announced the investigation and sought participation.

In 1993 a *Descriptive Report* (Land Conservation Council 1993) was released for public comment. The report consolidated background information on the biophysical character of Victoria's marine environment, its current and potential use and associated socio-economic opportunities, and ways in which its future use could be planned. It was collated with the guidance of technical specialists and included input from the commercial fishing, recreational fishing, petroleum and conservation sectors.

The ideas and input from public comment and a July 1993 stakeholder summit to discuss the implications of the *Descriptive Report* were consolidated in proposals that were released in 1995. These were the first of four sets of proposals that were published in 1995, 1996, 1998 and 1999, and were then finalised in 2000. The proposals evolved in the light of public input, at each stage, and the collection of additional information that examined the socio-economic aspects and practicality of various approaches to the design of marine protected areas, and the size and location of individual protected areas:

- the 1995 proposals (Land Conservation Council 1995) outlined arrangements for the ecologically sustainable use of the entire marine environment and proposed a five-zone schema to give effect to this;
- the 1996 proposals (Land Conservation Council 1996) retained arrangements for the ecologically sustainable use of the entire marine environment. The concept of zoning was retained but given less prominence. Discrete areas were identified and termed 'marine parks' where the objectives were the protection of habitat and biota. The parks contained a sanctuary zone that was highly protected; some forms of harvesting were permitted outside this zone, subject to their meeting specific conditions and being determined by a management plan for the park;
- the 1998 proposals (Environment Conservation Council 1998) continued the zoning concept; and
- the 1999 proposals (Environment Conservation Council 1999) retained arrangements for the ecologically sustainable use of the entire marine environment; however, these proposals made no explicit reference to zoning as a concept. The terms 'marine national park' and 'marine sanctuary' were introduced to describe discrete areas where the objective was to protect biota and habitat consistent with IUCN Protected Area Management Category II. These areas covered some 6.2% of Victoria's marine estate.

Final recommendations were provided to Government in August 2000 (Environment

Conservation Council 2000). Forty-six recommendations were made for the ecologically sustainable use of Victoria's marine waters and these included a system of 13 marine national parks and 11 marine sanctuaries covering 6.2% of the Victoria's marine waters. The system was based on the nationally endorsed principles of 'comprehensiveness', 'adequacy' and 'representativeness' (Australian and New Zealand Environment and Conservation Council Taskforce on Marine Protected Areas 1998).

In May 2001, Government largely accepted the recommendations (Victorian Government 2001) and announced that it would proceed immediately with legislation to establish a system of marine national parks, a position consistent with the policy on which it had campaigned prior to winning Government in 1999. At the same time the Government announced a $A40million funding package that included funds to substantially boost compliance by marine fisheries, with specific additional resources to target theft of abalone.

Legislation was introduced on 17 May 2001, but within a month Government withdrew its Bill, when it became obvious that the major opposition party would not support some key provisions. Although it withdrew the legislation the Government confirmed its continued commitment to establishing a system of marine national parks.

Following further discussion with key stakeholders and negotiation with the major opposition party, the leaders of the Government and the Opposition announced early in 2002 that they had reached in principle agreement on redrafted legislation. The redrafted legislation contained:

- the inclusion of one marine national park and marine sanctuary previously not accepted by Government and boundary amendments to some other previously accepted parks, and
- a statutory compensation scheme to provide transitional financial assistance to eligible commercial fishers and an associated independent process for assessment and appeals.

The redrafted legislation was introduced in May 2002, and on 13 June it had passed the Upper House. It became law a few days later, establishing the park system on 16 November 2002.

COMMUNITY ENGAGEMENT

As Bishop and Davis (2002) argue, participation in public policy 'is best understood as a discontinuous set of techniques, chosen according to the issues in hand and the political imperative of the times'. In this instance, the engagement process took two dominant forms – the provision of information and consultation – both of equal importance.

In the nine years leading to the finalisation of recommendations to Government, six reports were formally published. These were widely dispersed initially in hard-copy format but subsequently in hard-copy and electronic format. In each instance the print, radio and television media outlined the content of the reports and often provided editorial comment on the implications.

Despite the technical character of the reports, more than 4500 written submissions were made. Both the Land Conservation Council and the Environment Conservation Council arranged meetings in coastal towns to discuss the proposals, and these tended to be dominated by local issues or by the views of the dominant and more articulate participants. Meetings with key stakeholders – elected officials and executive staff of representative business, conservation and local government organisations, and opinion leaders – commenced in 1991 and were a feature throughout the process; they helped determine and clarify the various options in terms of the views of State and national membership organisations.

Consultation, as Bishop and Davis (2002) and Kane and Bishop (2002) note, assumes that those being consulted have the capacity not only to comment, but also to influence the final policy decision. In the context of public policy this does not mean that consultation determines the final decision; this is the role of Government and, where legislation is required, Parliament. Option generation and evaluation was a challenging process for all involved, given that it required consideration of three interrelated issues:

- the nature of the planning approach to the entire marine estate;
- a model for the marine protected areas, zoned or non-zoned; and
- the location and size of individual marine protected areas.

The relevance and application of the concept of multiple use at different spatial scales are inherently complex, especially when those responsible are seeking to integrate the needs of different sectors that may have competing needs, while also addressing the needs of future generations. Along with this, other related policy reforms were taking place within Victoria and Australia that in some instances led to a diffusion of effort and to uncertainty in the community as to where best to direct effort and comment.

Nevertheless, two high-order issues emerged through the consultation process that were directly incorporated in the final advice to Government and were subsequently adopted. First was the need to ensure that the policy response addressed the ecological sustainability of the entire marine environment. The second was the need to provide, wherever possible, certainty to industry and the community; this meant there was little support for options that left questions of access to fish and shellfish within the protected areas to subsidiary planning processes that conventionally would be undertaken on an area-by-area basis. With respect to the individual protected areas, consultation also led to iterative changes in their location, size and boundaries in order to minimise short-term socio-economic impacts. These changes continued throughout the process of option development that led to the final advice to Government, and again as result of further amendments by Government prior to establishment of the protected areas in legislation.

IMPLICATIONS

With the case study so recently concluded, there is no doubt that with ongoing analysis its implications will continue to be discussed and refined. However, three issues are already readily apparent that could usefully form the basis for consideration in other fora. They are inter-related and deal with the duration of the public policy process, the scope and detail of the policy, and the establishment of a broad basis for community engagement.

Duration of public policy development

The first implication relates to the duration of the process. Eleven years of effort is substantial by any standards. It is a long time for a single individual to be involved. For community and professional organisations, it raises major issues regarding continuity of input for elected officials who may have terms of one to three years, but also for professional staff.

However, although 11 years is a long period, it is far from unusual, and this is illustrated by one example. In the early 1990s Australia undertook a major discussion of what the concept of ecologically sustainable development meant in practice – fishing was amongst a range of sectoral and intersectoral issues considered. In the mid 1990s Victoria reformed its approach to fisheries management through legislation that enshrined this concept. Even given this significant reform and two parliamentary enquiries that dealt with access to fish stocks and fisheries management in the past decade, discussion and debate about access to stocks by recreational and commercial fishers in bays, inlets and estuaries remains a topic of enduring public debate.

Policy debate on substantial issues does not happen overnight; if the time frame is substantial, elections in representative democracies will occur, other policy initiatives may emerge, and – most important in terms of community participation – acceptable norms for community engagement may change. Various commentators (e.g. Putnam 2000) have identified a range of issues affecting participation in civil society with implications for establishing normative standards with respective to public policy development. The case study period, 1991 to 2002, saw an explosive growth in the availability and use of the Web and Internet in Victoria, and this change shaped the engagement process particularly in 2001/02. Government used the Web as an increasingly important means for the publication of material, community-based discussion sites provided a forum independent of government to exchange ideas, and community members used email to lobby members of parliament.

Scope and detail of policy

The second implication relates to scope and detail. The case study addressed issues at a jurisdiction-wide level and, in addition, identified the location of the marine protected areas (MPAs) and also explicitly defined the management objectives for these.

Over the 11 years, various participants questioned whether a more modest approach would have provided a more manageable process – for example, addressing the issue on a bioregion-by-bioregion basis, or only identifying the location of the MPAs and leaving determination of the management objective to subsidiary processes.

There are several indications that a single large comprehensive approach was the most beneficial in this instance. By addressing the entire marine jurisdiction rather than parts of it, local communities could develop and consider proposals in their area in the context of Victoria as a whole, and representative bodies that had State-wide or national interests could see and calculate the implications at local and subregional levels as well as across the entire jurisdiction. These benefits would have been impossible if planning had been undertaken separately for each of the five Victorian bioregions. In addition, previous Victorian experience with MPAs suggests that even if only one bioregion had been chosen for investigation it is unlikely that the policy process would have been much shorter.

Establishing a broad basis for community participation

The third implication from the case study is the importance of establishing a broad basis and opportunity for community participation. We have previously briefly referred to the involvement of representative bodies and constituencies in the engagement process; we shall now consider the general public as defined by the OECD (2001).

If we use Victorian media commentary as a yardstick, then the evidence suggests that initially Victoria's marine environment was largely unknown, possibly dangerous and devoid of any conservation merit in its own right or in comparison with other marine areas such as tropical coral reefs and Antarctic and Arctic waters. It was only in the latter part of the policy process when visual information showed Victorian waters for what they were – diverse, colourful and alive - that the general public came to realise what was at stake in terms of concluding a policy debate about MPAs.

These anecdotal observations appear to be confirmed by 2001 polling about the south-eastern Australian marine region, a region that included the case study area but is about 1000 times larger in area (National Oceans Office 2002). The polling results found, when segmented into groups based on their self-reported knowledge, that:

- 2% knew 'a lot' and placed a high importance on community involvement in planning;
- 15% knew 'a moderate amount' and were generally more interested than other subgroups in caring for the marine environment, spending more on reefs and banning foreign fishing;
- 45% knew 'a little bit'; and
- 37% knew 'basically nothing about the region', had less desire for additional expenditure on the region, and were less likely to care as much about the deeper ocean as the land. They were also less interested in community involvement in planning.

Work by the Australian National Oceans Office and USA-based organisations, Seaweb (Mellman Group 1996) and The Ocean Project (Belden Russonello and Stewart and American Viewpoint 1999), suggest that there is a compelling case for increased communication about the marine environment if there is to be broad-based community input to marine environmental decision-making. There is clearly a role for organisations responsible for community engagement to ensure that the general public are provided with information, about the substance and implications of the policy debate, that is beyond simple procedural issues on how to, when to, or in what way, they may become engaged.

THE CHALLENGE AHEAD

Initiatives such as the one addressed by this case study provide practical examples that establish benchmarks and normative standards that lead to 'bottom-up' development of national and international policy. What constitutes effective community engagement will continue to evolve, to be codified and to be informed by this practical experience. The 1992 inclusion of Principle 10 of the Rio Declaration on the Environment and Development, the 1998 Aarhus Convention, and the 2001 OECD publication *Engaging Citizens in Policy Making: Information, Consultation and Public Participation* are examples of this evolving process that must be seen as a vital part of broader policy debate about a sustainable future of the marine environment that covers 70 % of the Earth's surface.

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MARINE PROTECTED AREA IN REPUBLIC OF MALDIVES

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Abstract

Methods used in producing a plan of management for a protected area on the Republic of Maldives are demonstrated. The protected area is a pilot program under the Maldives Protected Areas Systems (MPAS) project, an AusAID-funded three-year program that commenced in early 2000. The goal of the project is to contribute to the protection of ecological resources in the Maldives and thereby support the long-term ecologically sustainable development and biodiversity of the country. The core activities under the MPAS are the establishment of two pilot sites in the Maldives. The establishment of the pilot sites is designed to equip the local community as well as the Government of Maldives with the techniques for management and monitoring of protected areas. The first pilot project is in the far south of the country, on Addu Atoll. The site is small in total size but contains complex ecological structures of coral reefs, seagrass beds, mangrove stands, agricultural activities, freshwater systems supporting unique bird populations, and important traditional sites. As with many remote communities involved in conservation projects, the communities in Addu Atoll are not familiar with deciphering resource maps or disseminating biological reports. In order to facilitate the development of a management plan for the area, a 1:750 scale model has been constructed near the site. The scale model is being used to represent resource maps produced from biological and community surveys. The level of information and then methods of displaying this information are described.

***Keywords**:* Maldives, 3D model, community, management

INTRODUCTION

In Maldives, the term 'protected area' has until recently been used to describe a defined area, established for a particular purpose, usually a recreational dive site. These sites are formally known as 'protected dive sites' but are often referred to as protected areas. This misnomer has created confusion among stakeholders, because many are unfamiliar with the concept of a representative and adequate system of protected areas, established to serve a variety of objectives, including the preservation of biodiversity.

The Maldives Protected Areas System project (MPAS) is an AusAID-funded bilateral project. It began with a feasibility study early in 1997, followed by the establishment of an office in the capital, Male, early in 2000. Australian Marine Science and Technology Pty Ltd (AMSAT) manage the project. The stated goal of the project is: '*to contribute to the protection of ecological resources in the Maldives thereby support long-term ecological sustainable development and biodiversity maintenance*'.

The project focuses on equipping the agencies and communities of Maldives with the tools for developing a system of protected areas. At the beginning of the project, it was evident that there were differing perceptions as to what a protected area contributes to the local environment and what it means in terms of supporting sustainable management of the entire atoll. This paper focuses on the process used to establish the system of protected areas.

THE PROCESS

Initially, two pilot or prototype protected sites were to be established. These pilot sites were to represent the types of environment and unique features of the country. The first of these is situated in the most southern part of Maldives, Addu Atoll (Fig. 1).

There are many names and accompanying definitions used to describe protected areas. Usually these relate to either a marine or a terrestrial protected area. The first pilot site in Addu Atoll encompasses a terrestrial and a marine area. Consequently, the definition of what the 'protected area' would look like and how it would function was more complex than the existing 'protected dive sites' already in place in Maldives.

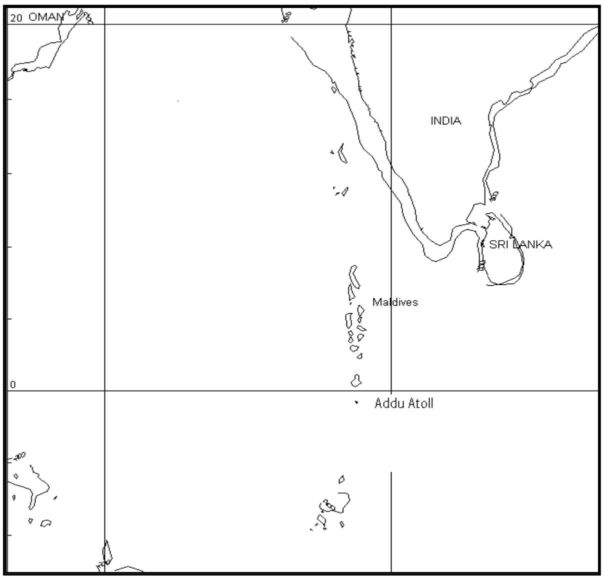

Fig. 1. Maldives and the position of Addu Atoll.

The strategy adopted for this project was to choose and assess a site-selection process, undertake biological and socio-economic surveys on the site and establish the boundaries and management options. This was to be followed by a community participation program, the instigation of an educational program and, finally, the transfer of skills to local residents.

Recommendations arising from this focused on changes to legislation and institutional arrangements, community-awareness schemes and the level of assessment and monitoring required as well as on the type of management plan that could be adopted for the pilot site.

SITE SELECTION

Maldives consists entirely of a series of atolls and associated coastline structures (Pernetta 1993). On many of the atolls the mangroves, marches and wetlands, seagrasses and algal communities have unique features. The geology and geomorphology of the islands are less well known. Limited studies have been done to catalogue the biodiversity of Maldives. Hence, the method used to select the pilot site was a combination of community and expert-panel submissions and the analysis of existing information on natural resources. The site-selection process assumes that community participation is a continuous task throughout the process. Participation was initiated through public announcements in the media followed by a targeted questionnaire or survey. Each site was rated on factors concerning biodiversity significance, stakeholder support, economic and social importance, representation of the particular management regime, present or future threats, logistics, availability of existing information and co-operation with existing programs. The site-selection process is summarised below:

1. Public announcement;
2. Expert panel – Community questionnaire – Assessment of existing information;
3. Candidate sites identified;
4. Protected area criteria applied (adequate and representative) – sites rejected;
5. Documentation of selected sites – site set aside for future selection;
6. Field surveys and desktop review;
7. Application of international standards (ICUN) – (more information may be required, see Stage 4.);
8. Rapid field survey to catalogue specific attributes;
9. Draft plan of management;
10. Site endorsed by stakeholders (return to Stage 4 if necessary);
11. Declaration of site including the formation of a management committee;
12. Plan of management activities implemented;
13. Plan of management refined through community consensus;
14. Budget prepared; and
15. Monitoring and reporting guidelines established.

The word "atoll" is derived from "atolhu", a traditional name in the Maldivian language. The Maldives archipelago contains 26 geographic atolls with an estimated total of 1192 islands. These are arranged for governmental purposes into 20 administrative groups (Ministry of Environment 2001). Within the administrative area there are 199 inhabited islands that make up the Republic of Maldives.

The formation of atolls is believed to be a result of the formation of volcanic islands in deep tropical waters. These volcanic islands give coral polyps a foundation from which to grow. Over time, the volcano becomes dormant and begins to subside. The coral reef that originally fringed the volcanic island becomes the barrier reefs. The coral atoll is the only remaining structure after the original island has weathered away (NASA http:// earthobservatory.nasa.gov/study/ Maldives).

The lack of terrain (no island is higher than 3 m) and small land surface area (only 33 islands having in excess of one sq km of area above sea level) of Maldives are limiting factors for species richness and biodiversity of the islands and cays. Maldives is also relatively isolated from large continental landmasses. There has been human occupation of the islands for over 2500 years (Woodroffe 1989).

SITE DESCRIPTION

Addu Atoll, the southernmost atoll in Maldives, is the focus of a regional development program as part of the Maldivian Government's decentralisation policy. It is isolated at latitude 0° 38'S and separated from the nearest atoll to the north by the deep Equatorial Channel, which is 45 nautical miles wide. The nearest atoll to the south is Salomon, approximately 320 n miles away and part of the Chagos Archipelago, which is not part of the Maldives administrative area. Addu Atoll is therefore relatively isolated in terms of ecological influences. The short studies undertaken as part of this project suggest that the Atoll is most likely self-generating in terms of marine recruitment, although there is an annual influx of avifauna from the other areas (Zuhair *pers. comm.* 2002).

The first pilot site is on the northern end of Hithadhoo, an island of Addu Atoll (Fig. 2). The site is representative of many of the biological, cultural, community and institutional issues that face the Government of Maldives and many other small-island developing nations. The intended protected area encompasses the top section of the island and extends offshore around the peninsula to include fringing coral reefs and islands. The area is of conservation significance because it contains regions of relatively open forest, mangrove forest, coral reefs, well-developed *kulhi* (shallow, brackish freshwater ponds) and seagrass meadows. The land has been modified by human action over a long period. The site has important cultural features, with graves and historical structures present. The site is used for agriculture, mainly coconuts and vegetables and the collection of traditional medicines. Collection of wood for fuel and the gathering of coral rubble and sand also occur. The area is a recreational area for the local community, with some boating activities and shore-based fishing. The near-shore areas, including the coral reef, are used by tuna fishers for bait collection using light attractants and lift nets while anchoring on the reef. The reef system and the maintenance of coral rubble on the shoreline create an important natural barrier for the low-lying island during high seas. The site has the potential to be a minor attraction for tourists.

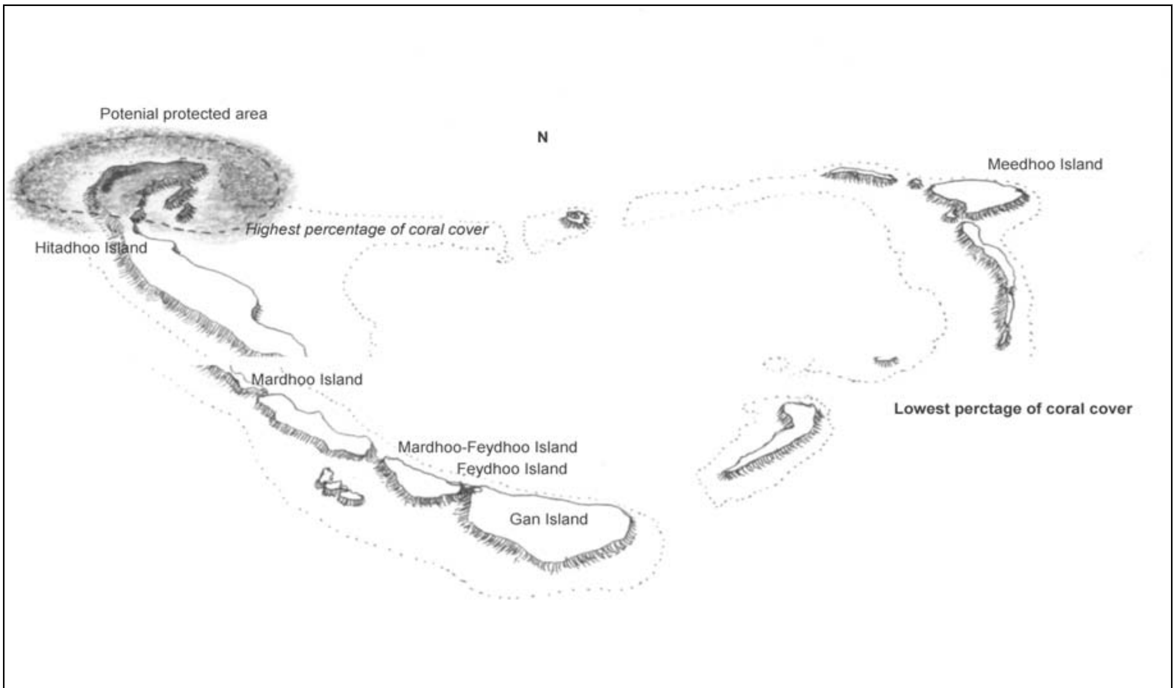

Fig. 2. Addu Atoll and individual islands, with the protected area on Hithadhoo.

The lagoon side of the proposed protected area on the eastern side of Hithadhoo is diverse in corals and fish species. There are large seagrass beds, and inner shallow lagoon areas connected to a relatively intact coral reef leading to a sharp drop-off into deeper water.

NATURAL, SOCIAL AND ECONOMIC VALUES

The natural values of the site were determined by a series of rapid surveys of the marine and terrestrial habitats and coastal formations. Socio-economic studies were also undertaken in the villages by random survey of households. The results allowed the team to develop profiles of the natural values of the site, identify any rare or threatened species and document evidence of impacts of human activities in the site as well as the socio-economic influence the natural resources have on the local communities. The results were reproduced in a three-dimensional scale model at a scale of 750:1 for use in community discussions and government consultations.

The findings of the biophysical surveys, combined with options suggested by the community, were used to draw up a plan-of-management proposal for the site. The rationale for each objective and action within the plan of management was supported by an over-arching document identifying constraints and recommendations.

The results were reported at three levels: policy, technical/manager and community. This strategy catered for the differing backgrounds of the stakeholders and required quite different types of reports and communication techniques to ensure that all levels were adequately informed. Communication at the policy and technical /manager level was via reports and workshops. Reporting to the community was through consultation, mainly using the 3D scale model.

CONCEPTS *V.* REALITY

The biological surveys of the site found that the terrestrial areas have important biodiversity values and the marine sector is vital to the sustainable management of the atoll ecosystem. The marine sector is of primary importance to the community through the fishing industry, although the contribution of fisheries to the national GDP has declined from 22% in 1978 to an estimated 6.5% in 1998 (Ministry of Environment 2001). Maldives now relies more on marine-based tourism, which makes up the major proportion of GDP (Ministry of Environment 2001). The marine survey of the atoll showed that only the coral reefs within the proposed protected area and along the northern reef section are intact and show little sign of the bleaching event that occurred in 1998 and degraded much of the reef system in other parts of Maldives (Zuhair 1998). The reefs in the proposed protected area were estimated to have 50% live coral cover with a wide range of species. This is in contrast to other sites in the atoll, mainly in the southern part, where estimates of live coral cover were as low as 2%.

In all community consultations and in the socio-economic surveys, the primary stakeholders (whether individuals or collective groups) were focused on issues relating to the conservation of land-based resources rather than the marine resources. The small proportion of the Maldives territory that is found above sea level may explain this. The terrestrial component of the site is used by many sectors of the community for recreational activities, collection of coral rubble, medicinal plants and firewood, and agricultural activities. Thus, the proposed site is important for local income generation. The terrestrial component is seen as an integral part of the protected area. Surveys, however, reflected the high level and long-term nature of human activity in the site. The terrestrial component of the site retains only limited biodiversity values.

Social surveys also indicated that the community has greater immediate and direct dependency on the terrestrial component of the protected area than they do on the marine sector, although the links between live coral, bait fishing and tuna catch are not well recognised at community level.

At a national level, there is recognition of the national dependency on the marine environment. This is reflected in a number of a national plans and strategies and is highlighted in the 6th National Development Plan of the Maldives.

CONSTRAINTS AND RECOMMENDATIONS

The role of protected areas in the sustainable development of an atoll, incorporating social, environmental and economic elements, is open to interpretation. The Republic of Maldives, along with most other marine nations, relies on the natural resources produced by marine plants and animals. The key to achieving sustainable environment and resource management is the development of a mechanism for integration of institutions that resolves conflict between social, environmental and economic issues and short-term income-generating priorities (Kenchinton *et al*. 2002)

As with many coastal states, Maldives has legislative overlaps between and within Ministries. The governance system of the Maldives is made up of sectors of individual strands of legislation, regulations and activities (Kenchinton *et al.* 2002). The translations of the Maldivian legislation suggest that each sector is largely independent of the others. This approach has served Maldives well in increasing the standard of health, education and well being. Maldives are now, however, facing the challenge of its impending graduation from Least Developed Country (LCD) status (UNDP 2002) and focusing on achieving and maintaining sustainability by carefully managing natural resources of the country.

There appears to be common understanding of what should be done to address the needs of sustainability and conservation at Ministry level. At the atoll level, the implementation of various Ministerial responsibilities often overlaps. It has been suggested that at island or atoll level, management for protected areas could reside with the Atoll Office. At atoll level, enforcement of virtually all legislation is the responsibility of officials of the Ministry of Atolls Administration. In the case of Hithadhoo, management of the proposed protected area could reside with the Atolls Administration, although the management and legislation of the area remains with the Environment Ministry. Management of day-to-day activities may be through a Protected Area Management Committee, chaired by the Atoll Chief. The suggested make-up of such a committee includes representatives of various stakeholder groups, such as the Island Offices, Women's Development Committee, fishers, business groups, agricultural leaseholders, Island Development Committee and elders. The establishment of a successful community management sector could reduce the need for extensive legislative changes.

CONFLICTS IN RESOURCE USE

The priority given by the community to the conservation of land-based attributes differs from the results suggested by the team of experts. Results of biological surveys link the preservation of the coral-reef system to the sustainability of the atoll as an entire ecosystem. The coral-reef system is an important habitat for baitfish. The availability of baitfish is the common limiting factor to the tuna pole-and-line fisheries at community level. Survey results also suggested that the coral-reef system in the protected area is the most likely source of coral recruitment for other reefs in the atoll. The maintenance of the recruitment stock is vital if there is to be recovery of live coral to the bleached areas in other parts of the atoll. The coral-reef system also functions as a natural barrier to storms and provides an asset for attracting marine-orientated tourism.

COMMUNITY PERCEPTIONS

As with many remote communities, many of the elders and other people collectively referred to as stakeholders are unfamiliar with the concept of deciphering aerial photographs, maps or satellite images. Many of the issues relating to marine protected areas are resolved around three-dimensional concepts of space. Elements contributing to a plan of management for the site revolved around the concept of atoll sustainability and a balance between environment and social economics. A constraint of the project is the community perception of what a protected area could achieve. The initial community concept of a protected area was a tourist park that could generate income through visitor numbers. Although some form of income generation may be possible in the future, the main focus of the project was to develop a management system that supported the concepts of biodiversity and sustainability.

To address this perception, a 1:750 relief scale model of the site was constructed in plywood on a table and housed under a traditional thatched-roof building. The scale model serves several purposes. It enables the community to have a focal point for the protected area; it demonstrates the issues of the site in a three-dimensional perspective and is a way of illustrating contemporary scientific results in a way that easily transcends language, culture and age differences. The scale model also helps to focus on the conflicting interests in a community.

A three-dimensional model acts as a 'bird's eye view' of the environment, enhancing analytical skills and perspectives, especially on interconnecting ecosystems. It helps to deal with issues and conflicts associated with the boundaries and resource use (www. prgaprogram.org/natural.htm).

DISCUSSION

As with many natural resource projects, the establishment of boundaries, activities within those boundaries and the make-up of the management committee proved to be issues that require resolution over time. At the time of compiling this paper, some of these elements have not been agreed. Use of the 3D scale model proved to be important when demonstrating the links between impacts of resource use and aims of the management plan. The model was successfully used to identify common areas of conflict and to focus stakeholders on the benefits of some of the management options and their links to sustainable management of the island and atoll.

The zoning of the reef as a non-fishing area proved to be the most contentious issue relating to the plan of management. The project recommended the coral reef area to be managed as category II, consistent with the IUCN category system. The optimum size and, to large extent, the objectives of a marine protected area determines its boundaries (Ward 2002). In the case of the Hithadhoo Protected Area, the community and fishers selected the boundaries on features that are easily recognised. The boundary markers are natural features such as the headland and a man-made channel through the reef (recently constructed to allow easy access for fishing vessels to bait fishing areas). Although the allocation of a larger area of reef to a no-fishing zone may better serve the entire atoll, further community consultation would be necessary over a longer period of time than the project duration allows.

Compromises inevitably arise as a part of the consultation process. To compensate fishers for loss of fishing sites, the installation of a fish aggregation device (FAD) was proposed. This FAD would be installed in the lagoon to act as a bait attractant and thus reduce the dependence on the protected area as a fishing site. A previous FAD was installed and recognised as successful by the local fishers before it was damaged. There are seven 'good' bait-fishing sites in the atoll of which the proposed protected area is one. At present, the Government of Maldives is installing FADs throughout the country as part of their fisheries policy. The other compromise suggested was that a no-fishing zone be enforced for a set period ranging from 3 to 5 years, during which monitoring data would be collected. Extension of the closure period would depend on whether advantages of management measures during the closure period were demonstrable to the stakeholders.

To support the maintenance of the biodiversity of the site, other recommendations relating to the terrestrial areas were made. The management of the kulhi and buffering vegetation was recommended to be category II under the IUCN categories. The remaining land area was to be IUCN category V. This would allow existing agricultural practices to continue and lease payments from agricultural activities to partially fund the operation of the protected area (all agricultural and resort areas are leased from the government).

It was clear that there had to be community support if the management of the different zones was to be successful, because the zoning would place restrictions on various activities that are undertaken in the protected area. Although some of these activities are not sustainable, they are important for community income. Community consultation showed that there is support for the reduction of many of the non-sustainable activities, such as coral collection, firewood removal and sand mining. There is also support for decreasing the number of access roads in the site to reduce impacts on the existing vegetation. There appeared to be broad support for the establishment of a no-take fishing zone but there were reservations on the enforcement issue. This proved to be the single most contentious issue.

Recommendations from the project assume that the management of each Atoll Protected Area in the national system would be controlled by a community-based system that operates to provide advice and support to the island-level administration. There could be several components to the day-to-day management of a declared protected area within an atoll.

Day-to-day management of a site would rest with the community. The community might choose to form a Protected Area Management Committee (PAMC), made up of representative stakeholders. This could include representatives from various sectors within the community and be chaired by the Atoll Chief. The Atoll Chief represents the collective Ministries, while the Island Office represents the daily activities within an island. The other nominated stakeholders are representatives of the various sectors within the Island and Atoll community. Conflict resolution and enforcement would most likely require supportive legislative.

Obtaining community consensus of all these issues involved many meetings. The scale model was a core tool in the consultation process to demonstrate impacts of the protected area. Issues that arose were not always about the zoning system and its implications, but on the make-up of the PAMC, the extent of fisheries restrictions, options for funding and the extent of enforcement required. Many of these are directly related to community issues and local options.

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DETERMINING REEF FISH ABUNDANCE IN MARINE PROTECTED AREAS IN THE NORTHERN MARIANA ISLANDS

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Abstract

Marine Protected Areas in the Commonwealth of the Northern Mariana Islands (CNMI) are a relatively new concept. The primary purpose of CNMI no-take Marine Protected Areas (nMPAs) is to enhance fish resources by protecting sections of the reef to serve as brood-stock and to provide fish 'spill-over' into adjacent areas. The measure of the early success of nMPAs hinges partly on the ability to measure fish abundance by statistical estimation methods. A stratified sampling approach was used to survey reef fish abundance in the Sasanhaya Bay Fish Reserve in Rota over a three-year period, and the Managaha Marine Conservation Area (MMCA) in Saipan over a four-year period. Stratifications were based on qualitative habitat characteristics and sample effort allocated proportionally by stratum size. The precision and coefficient of variation of the sampling method were evaluated for varying levels of sampling effort by computer simulations of sampled data sets. These measures provided guidance on sample size requirements and relative sample variability for future survey work. The ability to generate reliable estimates of fish abundance requires consistency in the fish counter, as well as reasonable identification of statistical strata. Providing a standardized, repeatable sampling scheme is essential to evaluating the success of nMPA over the long term.

Keywords: reef fish, MPA, Northern Mariana Islands, underwater visual census

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INTRODUCTION

The decline of fisheries stocks in many marine regions has cast doubt on the reliability and effectiveness of traditional single-species management approaches (Agardy 2000). In addition, the influence of fishing on marine ecosystems has become a pressing management concern (Sumaila *et al.* 2000), resulting in the development of Ecosystem Fishery Management Plans in some US Fisheries Management Councils (WPRFMC 2002). Increasing fishing pressures on fisheries stocks associated with finite benthic habitat have resulted in different approaches to fisheries management, with a leading management alternative being the establishment of marine protected areas, or MPAs (Côté *et al.* 2001). The importance of MPAs has become an increasingly prominent issue in fisheries management (Walters *et al.* 1999), as a means to protect and enhance brood-stock of harvested species via no-take zones that protect both fish and habitat, thereby providing recruitment and emigration to fished areas adjacent to or down-current of the MPA. The usefulness of MPAs in replenishing stocks of wide-ranging marine species is debatable (Sharp 2002).

The Mariana Archipelago includes three distinct archipelagos bordered by latitude 12'00°N to 21'00°N, and by longitude 142'00°E to 146'00°E (Fig. 1). The Southern Island arc (SI) comprises the islands and banks from Santa Rosa Reef south of Guam to Sonome Reef north of Farallon de Medinilla. Raised limestone-capped basalt cores characterize these islands and banks, with the islands exhibiting well developed reef systems. The geologically younger Northern Islands arc (NI) includes the banks and islands from Esmeralda Banks to Uracas Banks. The NI islands are basalt rock with reef development limited to fringing reefs. Both the islands and banks of the NI are volcanically active. In addition, roughly 145 to 175 km west of and parallel to the main island chain lies the West Mariana Ridge (WMR) comprising banks and reefs some of which rise to within 13 m of the surface. The Mariana Archipelago is divided into two distinct political entities in union with the United States of America: the Territory of Guam including Guam, its associated banks and reefs including Bank A in the WMR; and the Commonwealth of the Northern Mariana Islands (CNMI), which stretches from Rota Banks north to Uracas Banks, including the remaining features in the WMR (Fig. 1).

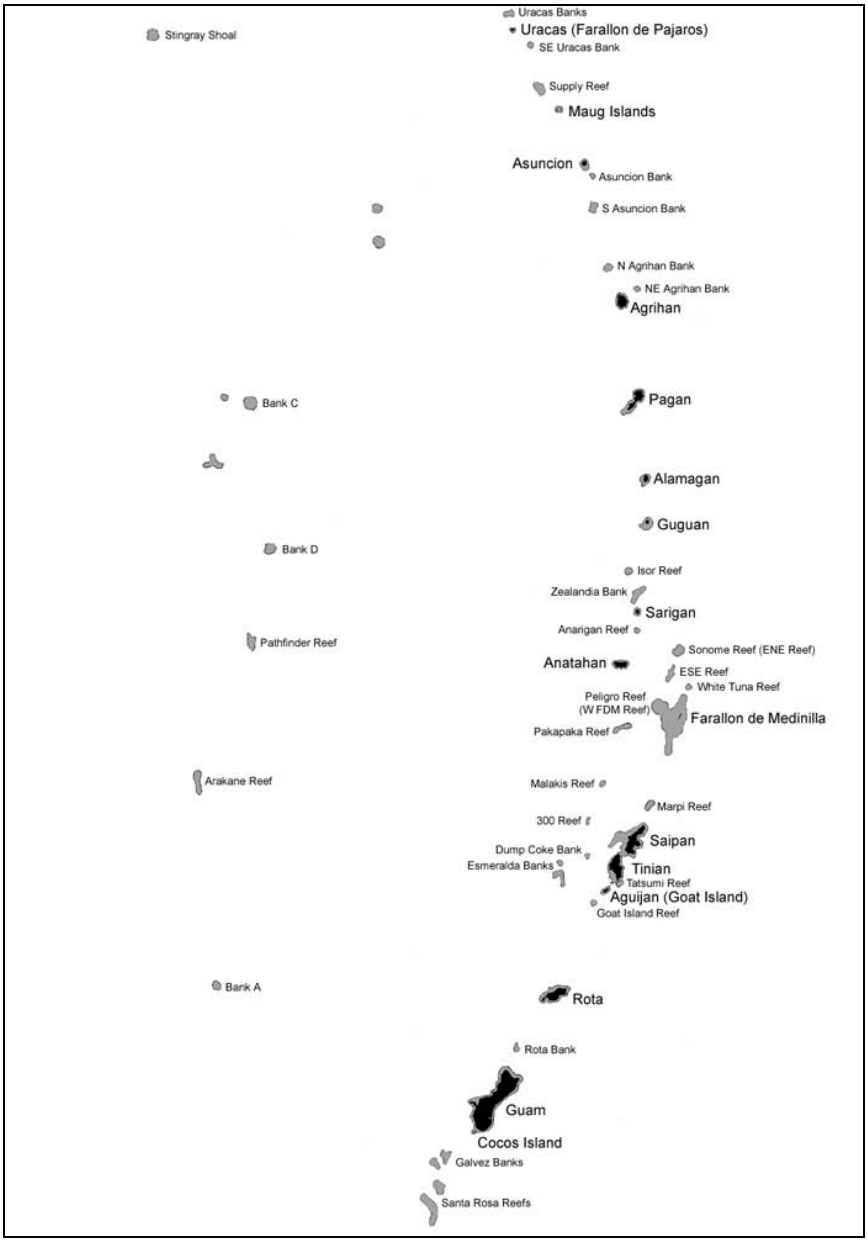


Fig. 1. The Mariana Archipelago

The concept of terrestrial protected areas was written into the CNMI Constitution with the designation of four NI wildlife reserves, the entire islands of Guguan, Ascunsion, Maug and Uracas. In 1985 the concept of the establishment of marine parks in the CNMI was explored when the CNMI Coastal Resource Management Office (CRMO) contracted to have marine parks proposed on the populated islands of Saipan, Tinian and Rota in the SI, the goal being a comprehensive approach to promote and enhance tourism (PBEC 1985). More recently, concern over declining catch rates around the populated islands of Saipan, Tinian and Rota in the SI raised concern over management protocols for coral reef fisheries (Trianni 1998).

In 1998 the CNMI Division of Fish and Wildlife (DFW) commenced a Marine Sanctuaries Program (MSP) with funding from the *Dingell-Johnson Sportfish Restoration Act* Program administered through the US Fish and Wildlife Service. The goal of the project was to provide funding for the monitoring and assessment of coral reef fish in existing no-take MPAs (nMPAs) in the CNMI, as well as to conduct surveys of all the islands for the designation of additional areas or islands that might serve as nMPAs. When the project began, only one nMPA was in existence, the Sasanhaya Bay Fish Reserve (SBFR) in Rota, which was designated in 1994. Shortly after the DFW MSP project commenced, a bill was introduced to create the Tinian Marine Sanctuary (TMS) on the island of Tinian, and the Managaha Marine Conservation Area (MMCA) around Managaha Island in Saipan Lagoon. All three of these nMPAs generally followed the geographical suggestions from the 1985 CRMO-funded study, although the 'no-take' provisions were added. The MMCA was subsequently passed into law in August 2000, but the TMS is yet to be enacted. Law enforcement of the SBFR did not begin until late 2000, and MMCA rules and regulations are still pending.

Although the CNMI nMPAs were established primarily for non-biological reasons, their statutory purposes were the fostering of fishery resources and protection of coral reef habitat. The CNMI DFW was given the responsibility of monitoring and assessment of these protected resources. To evaluate the effectiveness of the nMPAs with regard to enhancement of coral reef fish communities, an adequate sampling protocol needed to be established. Monitoring and assessment of the MMCA and the SBFR began in 1999 and 2000, respectively. The first years of data collection were viewed as preliminary to the long-term management of these nMPAs, serving as guidelines for future monitoring and assessment work. This paper documents the methods of assessing coral reef fish populations in the enacted MMCA and SBFR nMPAs.

METHODS

In order to formulate a monitoring and assessment protocol, it was first necessary to identify the reef fish species to be observed, and to develop a sampling method, an estimation procedure, and an evaluation process.

Targeted reef fish

The estimation of abundance was determined for 16 Families/subFamilies/groups or categories that were considered to be generally larger, visible coral reef fish species. These categories included commercially and recreationally desired species, species of aesthetic value to non-impact users, and species, e.g. chaetodontids, that serve as indicators of relative coral health (Table 1).

Scaridae were recorded as either 'Initial' or 'Terminal' phase, because the ratio of the phases (Terminal/Initial) was found to be indicative of fishing pressure in the CNMI (Trianni 1998). Acanthuridae were split into the Acanthurinae and Nasinae because both *Naso unicornis* and *N. lituratus* were primary target species in the CNMI (Graham 1993; Trianni 1998). In all, these categories were considered to encompass the characteristic composition of the assemblage of larger coral reef fish.

Table 1. Reef fish categories used in abundance estimation, Northern Mariana Islands.

Acanthurinae	Lethrinidae	Balistidae
Nasinae	Myripristinae	Chaetodontidae
Labridae	Holocentrinae	Lutjanidae
Scaridae Initial Phase	Mullidae	Nemipteridae
Scaridae Terminal Phase	Pomacanthidae	Zanclidae
Serranidae		

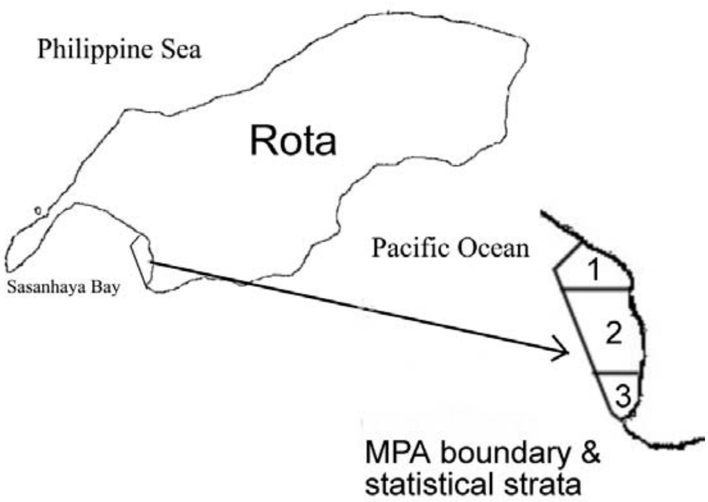
Sampling method

A 25 m by 5 m belt transect was chosen as the sample method to estimate reef fish abundance in the two CNMI nMPAs, the SBFR and MMCA. The nMPAs are relatively small, and the shorter transect length provided the opportunity to collect a greater number of samples during each dive. Studies have demonstrated that wider belt transects resulted in significant underestimation for some reef species (Cheal and Thompson 1997), as well as increased bias (Sale and Sharp 1983).

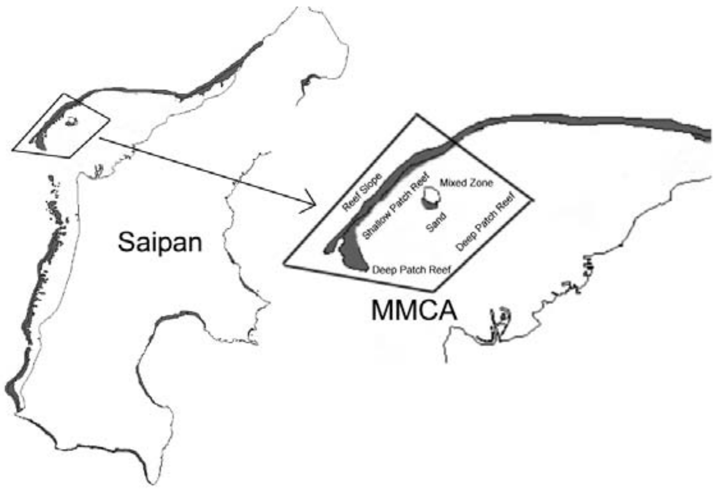
Transects were placed from a boat that was anchored according to a selection of haphazard reckoning and random Lat/Long seconds. After diver placement of a series of transect lines, the fish counter waited 5–10 min before proceeding with counts. Except for the MMCA 1999 survey, which used up to five fish counters, the same fish counter was used in all survey work. When the fish counter had covered about ¾ of the transect length, other data collection activities commenced. This procedure ensured minimal disturbance to the reef fish present along the belt transect during each count. For all surveys except MMCA 1999, 12–15 min were required to complete a single belt-transect count.

Abundance estimation

A stratified sampling protocol was chosen for abundance estimation. The assessment process began with determination of the nMPA boundaries. In the case of the SBFR the boundaries as stated in public law were vague, and the DFW determined the boundaries of the SBFR in March 2000. The SBFR comprises reef-slope habitat with a sand plain at about 33 m that forms the outer boundary of the nMPA. Five strata based on qualitative habitat characteristics of bottom type were initially identified in the SBFR by manta towing the length of the MPA three times in March 2000. On the basis of subsequent survey work, stratum number was reduced to three (Fig. 2).



(a)



(b)

Fig. 2. (*a*) The Sasanhaya Bay Fish Reserve, Rota Island. Numbers refer to statistical strata. (*b*) The Managaha Marine Conservation Area, showing statistical strata.

The public law creating the MMCA provided Lat/Long and UTM position boundaries, although the initial boundaries presented in 1999 differed from those enacted in 2000. Strata in the MMCA were initially identified inside the lagoon following a habitat typing of the Saipan Lagoon conducted in 1979 (Amesbury *et al.* 1979). The reef slope portion of the MMCA was aggregated as a single stratum, and the total number of strata was established at five (Fig. 2). The surface areas of the strata in each nMPA were determined initially by the dot-grid method (Barret and Philbrook 1970) and later corroborated with GIS. Maximum depth of nMPA surveys was restricted to 15.3 m to ensure adequate data collection and dive safety. The area used in estimation of reef fish abundance included the depth range from 0 to 18.3 m. To obtain estimates of required sample size the following equation was used:

$$n = \sqrt{s / p\bar{x}}$$

where n is sample size, s is sample standard deviation, p is precision, and x is sample mean.

The 16 categories of reef fish were aggregated to obtain single estimates of mean abundance and variance. Sample size estimates for the initial years of the nMPA surveys used proxies for mean abundance and variance from sampling of other habitats using a 25 m by 5 m belt transect. Precision was set at 30%, from rearrangement of the sample size formula. Subsequently, the target sample size for a new survey was determined by use of a combination of the highest variance and lowest mean from the previous survey, along with the weighted mean and weighted variance from the previous survey, at various levels of precision. Sample effort was allocated proportionally by stratum size.

Abundance estimation for the 16 reef fish categories followed a simple proportional stratified design, with standard estimators following Cochran (1977). *N* equaled the size (surface area) of the *h*th stratum, and stratum weights were defined as

$$W_h = N_h/N\ .$$

The unbiased estimate of the population mean was determined by

$$\overline{y}_{st} = \sum^{L} (W_h)\overline{y}_h$$

where y_h are the estimated stratum means, and y_{st} is the unbiased estimator of the population mean, *u*. The overall unbiased estimate of variance was determined as

$$\hat{V}(\overline{y}_{st}) = \sum W_h^2 (\frac{s_h^2}{n_h})(\frac{N_h - n_h}{N_h})$$

The unbiased estimate of total population size was then calculated as

$$\hat{Y} = N(\overline{y}_{st})$$

Bounds on the error of estimation were computed following Cochran (1977):

$$B = \pm 2\sqrt{\hat{V}(\hat{y})}$$

Evaluation

Since Brock (1954) first presented the concept of using belt transects as a method for estimating reef fish abundance, underwater visual census (UVC) techniques have become a standard tool in assessing reef fish populations. The reliability of UVC techniques has been examined in a comparative sense and through precision estimation (DeMartini and Roberts 1982; Sale and Sharp 1983; Bohnsack and Bannerot 1986; Thresher and Gunn 1986; Buckley and Hueckel 1989; Greene and Alevizon 1989; Samoilys and Carlos 2000). Estimates of accuracy and bias of UVC have been obtained for spatially restricted habitats by destructive sampling (Brock 1982; St John *et al.* 1990), and Watson *et al.* (1995) modeled bias in UVC belt transects using a computer simulation program.

To evaluate the relative effectiveness of the sample method and obtain estimates of the relative variability of sample data within each stratum of each MPA, precision (SE/mean) and the coefficient of variation (CV, SD/mean), respectively, were estimated from collected data. Algorithms were written in S-PLUS (ver. 3.3) to conduct simulations to estimate precision and CV over increasing sample size. Each sample size was simulated 250 times with replacement. Data for each stratum in each nMPA were combined for all years sampled, thereby including a comprehensive variability in the data set.

RESULTS AND DISCUSSION

The comparison of the proportional sample allocation versus the actual sample allocation for the MMCA is shown in Table 2. Direct adherence to sample size and stratum-based proportional allocation were not exactly attainable owing to logistical problems and weather conditions.

The results for abundance estimation in the SBFR and MMCA are shown in Figures 3 and 4. Categories that did not have estimates for all surveys for an nMPA are not shown. In the MMCA these categories included Nemipteridae and Lethrinidae, and in the SBFR, Nemipteridae, Lutjanidae, and Holocentrinae. For the MMCA, estimates from the 1999 survey for each category presented exceed almost all subsequent years' estimates. The most apparent characteristic of the four surveys was the relatively high estimates from the 1999 data for some of the categories. Most notably, Acanthurinae and Nasinae were significantly higher in 1999 than in subsequent years. The 1999 Nasinae estimation exceeded that of the 1999 Acanthurinae estimation. Other categories that exhibited exceedingly high values for 1999 were Balistidae, Lutjanidae and terminal-phase Scaridae.

Table 2. Comparison of actual sample size taken (A) versus proportional sample size taken (P) for the MMCA and SBFR.

Strata	1999	2000	2001	2002
MMCA	**A:P**	**A:P**	**A:P**	**A:P**
Reef Slope	21:15	11:14	12:10	11:6
Deep Patch Reef	30:27	46:26	22:19	13:10
Shallow Patch Reef	8:11	8:10	6:7	6:4
Sand	7:11	4:10	3:7	7:4
Mixed	6:8	4:8	6:6	9:3
Total	**72:72**	**73:68**	**49:49**	**46:27**
SBFR				
Stratum 1		8:8	7:9	10:9
Stratum 2		22:22	24:18	20:19
Stratum 3		NA	8:6	12:6
Total			**39:33**	**42:34**

Category estimates from 1999 for moorish idol(Zanclidae) exceeded chaetodontid estimates in subsequent survey years. For some of the more cryptic species, such as the groupers (Serranidae) and holocentrids, estimates were relatively consistent with, or below, subsequent years. The same was true for the labrids. Holocentrids were estimated as a Family in 1999, and the combined estimates of Myripristinae and Holocentrinae from subsequent years were comparable to the 1999 Holocentridae estimate (Fig. 3). As previously stated, the 1999 MMCA survey was conducted with five fish counters of various levels of experience, with no preliminary observer standardization

As the lack of planning led to spurious abundance estimates, these initial data were excluded from further analysis.

In contrast to the MMCA survey, the SBFR surveys utilized the same fish counter for all surveys. No single year dominated the estimates (Fig. 4). Large inter-annual variability was observed in some categories, and error bounds generally increased as category estimate decreased.

Simulation results are shown for the MMCA and SBFR in Figures 5–8. When sample size increased, precision decreased, with a corresponding decrease in the measurement deviation. In contrast, the mean CV remained relatively constant over sample size, appearing in most cases to approach an asymptotic value. What did change significantly in the CV estimates were the large measurement deviations at low sample sizes, suggesting that an adequate sample size will be required to obtain an approximate estimate of the true mean value. The CV is a dimensionless estimate of the relative variability in the sample data (Hillborn and Mangel 1997), and here a reflection of the relative variability in the habitat or stratum. Obtaining accurate estimates of the true variability in the sample data is critical to obtaining good estimates of required sample size, in addition to establishing a useful optimal stratified sampling design.

The sample sizes required to achieve various levels of precision are shown for both the MMCA and the SBFR in Table 3. In the MMCA, significant variability in sample size was observed for differing levels of precision. Values for CV also differed considerably between the MMCA strata. For example, the sand stratum required 48 samples to achieve a precision of 20%, and the CV was estimated at 146%. In comparison, the reef-slope stratum indicated that only 2 samples were required to achieve a precision of 20%, with an estimated CV of 36%. Examination of both precision and CV for the MMCA strata indicates that nearly all strata are distinct, and although the reef slope and shallow patch reef are very similar in their values for both measures, the ecological differences in these strata separate them.

In the SBFR, the number of samples necessary to attain a predetermined level of precision was much lower than in the MMCA, primarily as a result of the between-strata homogeneity in habitat type, because all SBFR stratum are reef slope habitats. The SBFR precision and CV were relatively similar between strata in comparison with the MMCA, and strata 1 and 2 can be considered a single stratum, whereas the precision and CV values for stratum 3 indicate that this stratum should remain separate. On the basis of these results, the SBFR can be reduced to two strata.

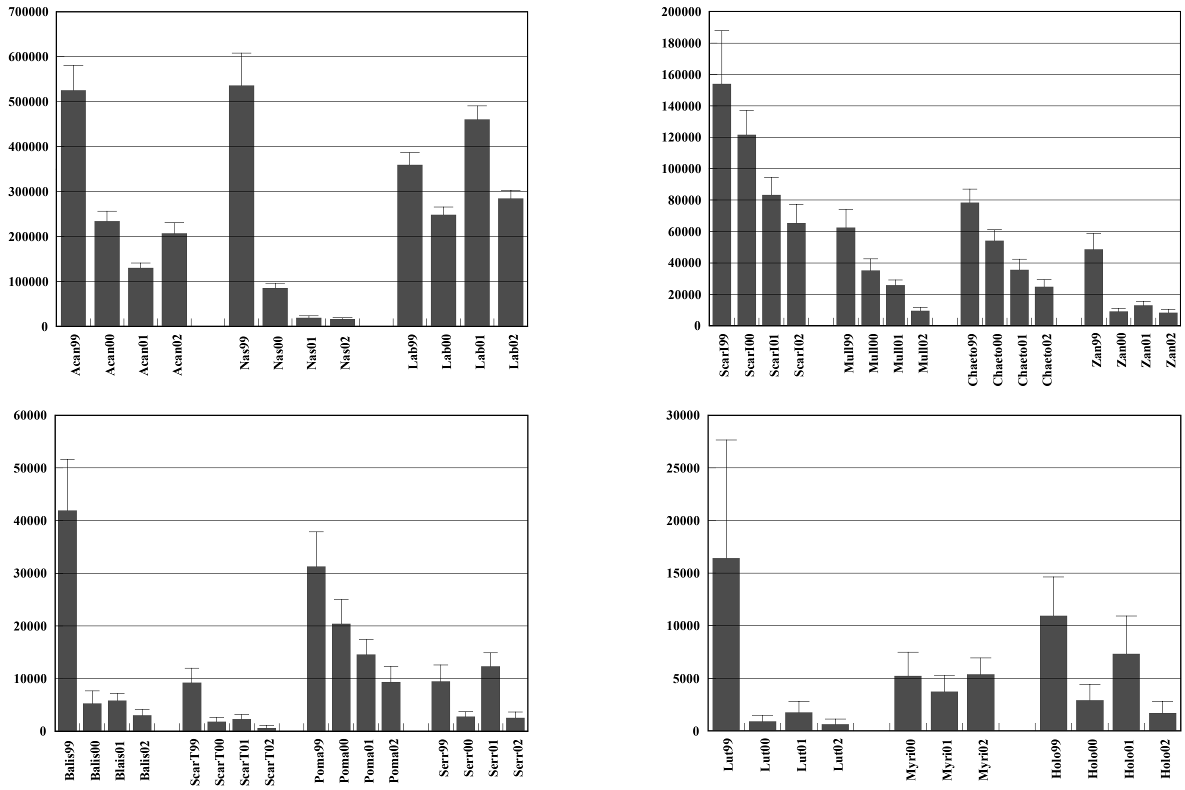


Fig. 3. Abundance estimates from the MMCA surveys. Acan=Acanthurinae, Nas=Nasinae, Lab=Labridae, ScarI=Scaridae Initial Phase, ScarT=Scaridae Terminal Phase, Mull=Mullidae, Chaeto=Chaetodontidae, Zan=Zanclidae, Balis=Balistidae, Poma=Pomacanthidae, Serr=Serranidae, Lut=Lutjanidae, Myri=Myripristinae, Holo=Holocentridae.

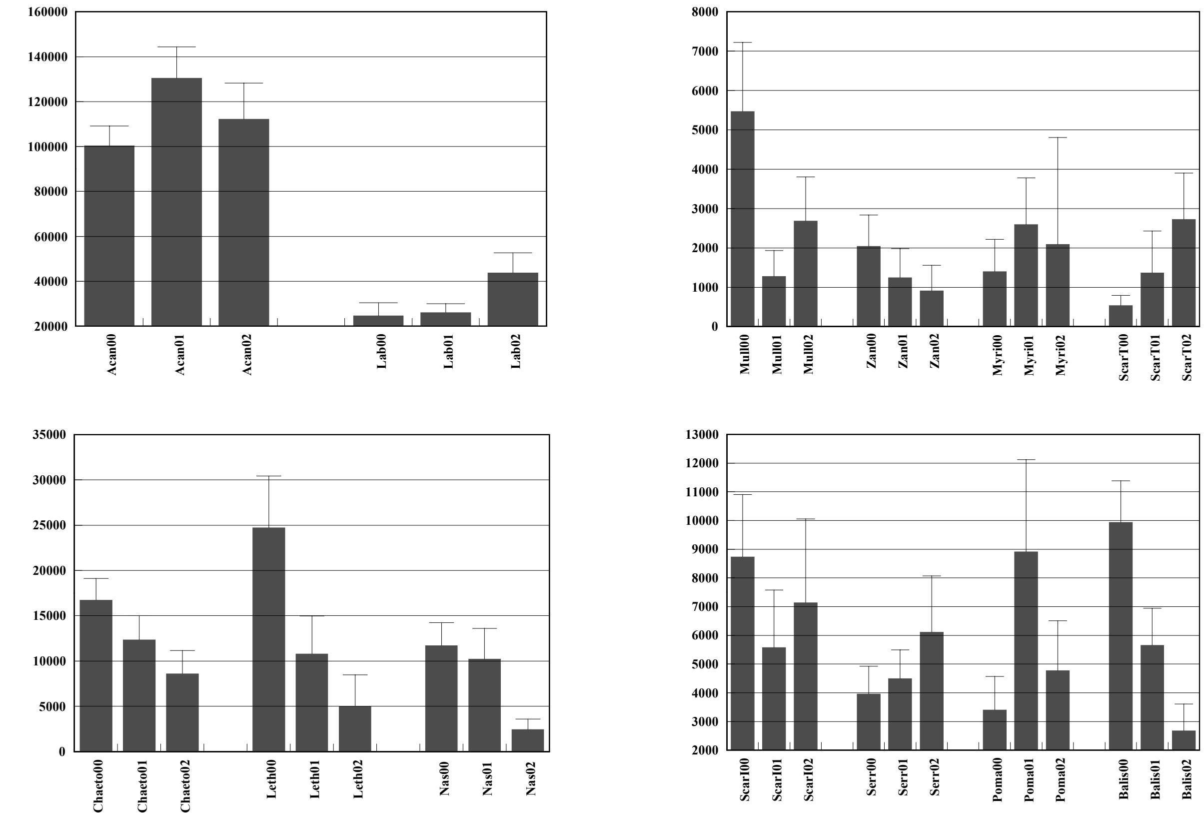


Fig. 4. Abundance estimates from the SBFR surveys. Acan=Acanthurinae, Nas=Nasinae, Lab=Labridae, ScarI=Scaridae Initial Phase, ScarT=Scaridae Terminal Phase, Mull=Mullidae, Chaeto=Chaetodontidae, Zan=Zanclidae, Balis=Balistidae, Poma=Pomacanthidae, Serr=Serranidae, Lut=Lutjanidae, Myri=Myripristinae, Holo=Holocentridae.

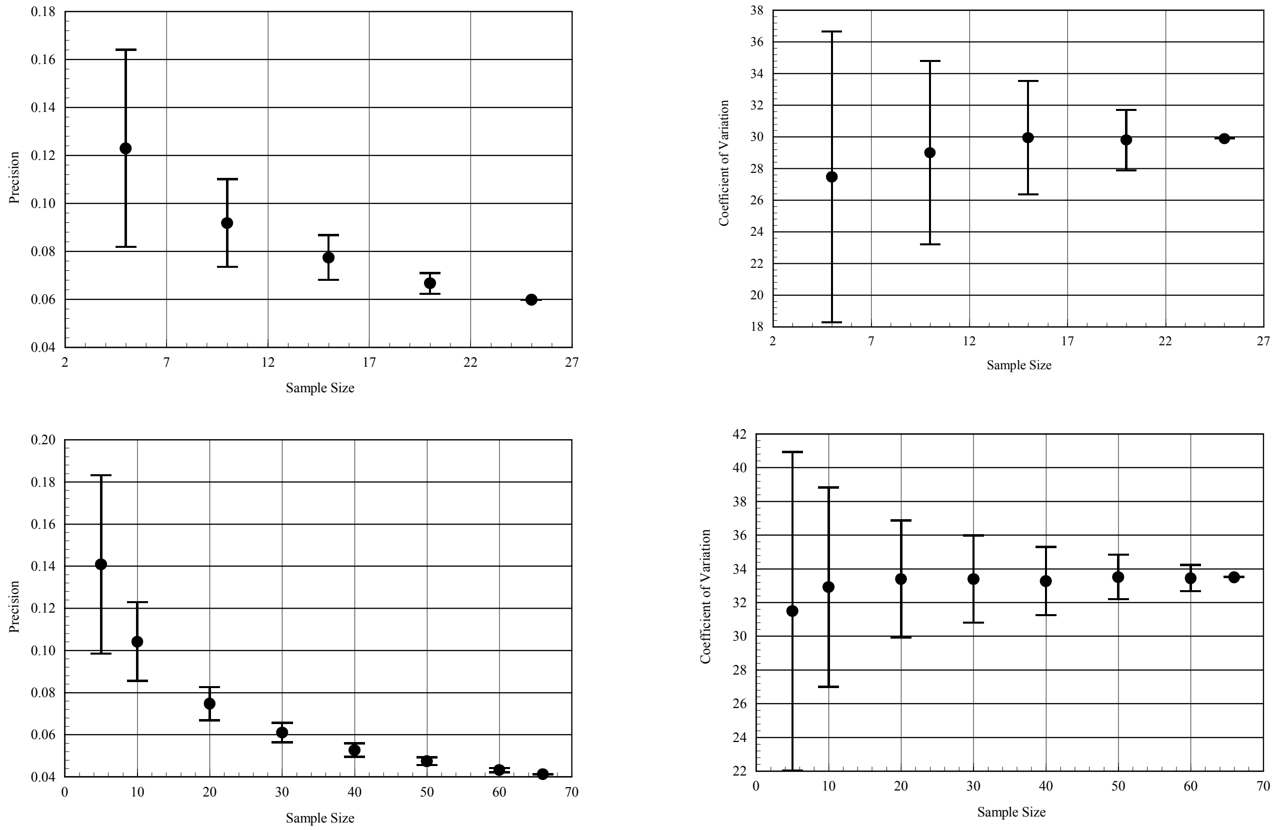


Fig. 5. Precision and coefficient of variation with increasing sample size for (*top*) stratum 1 and (*bottom*) 2 in the SBFR.

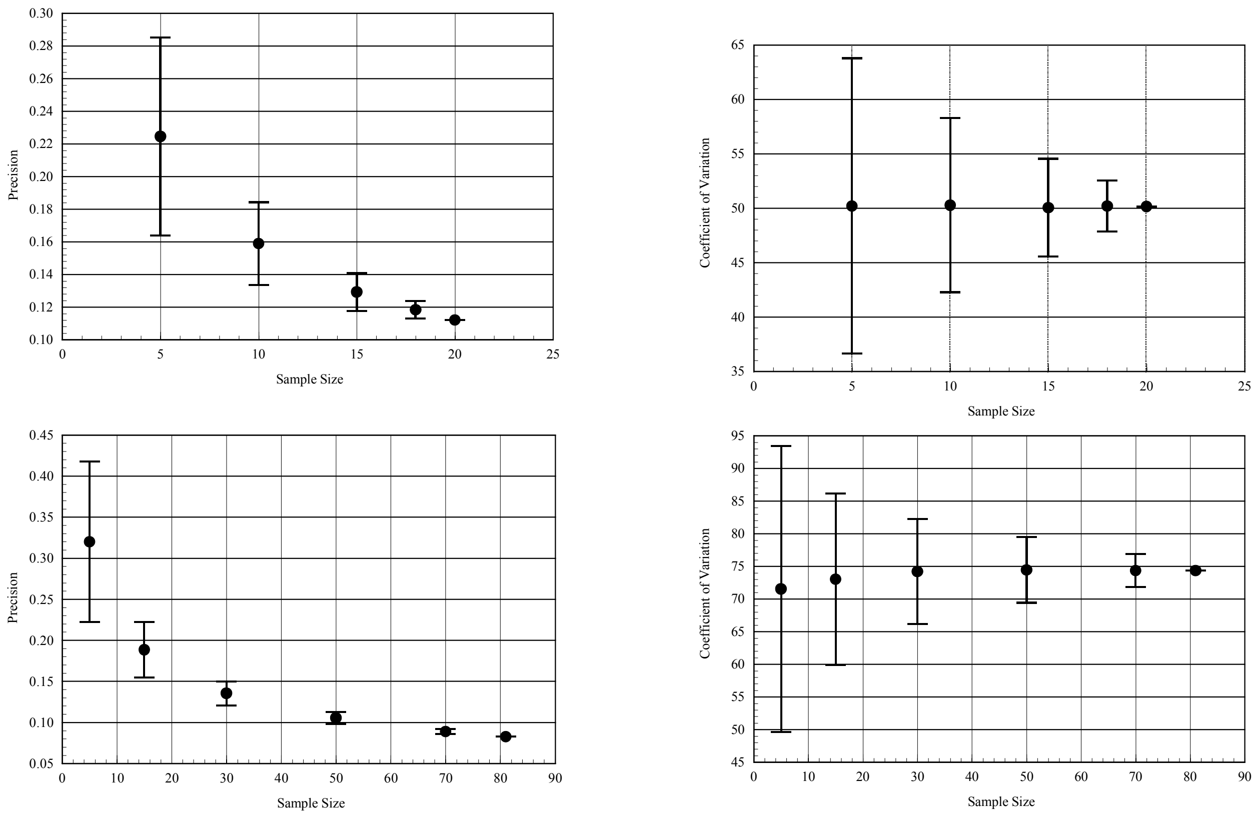


Fig. 6. Precision and coefficient of variation with increasing sample size for (*top*) stratum 3 in the SBFR, and (*bottom*) the Deep Patch Reef Stratum in the MMCA.

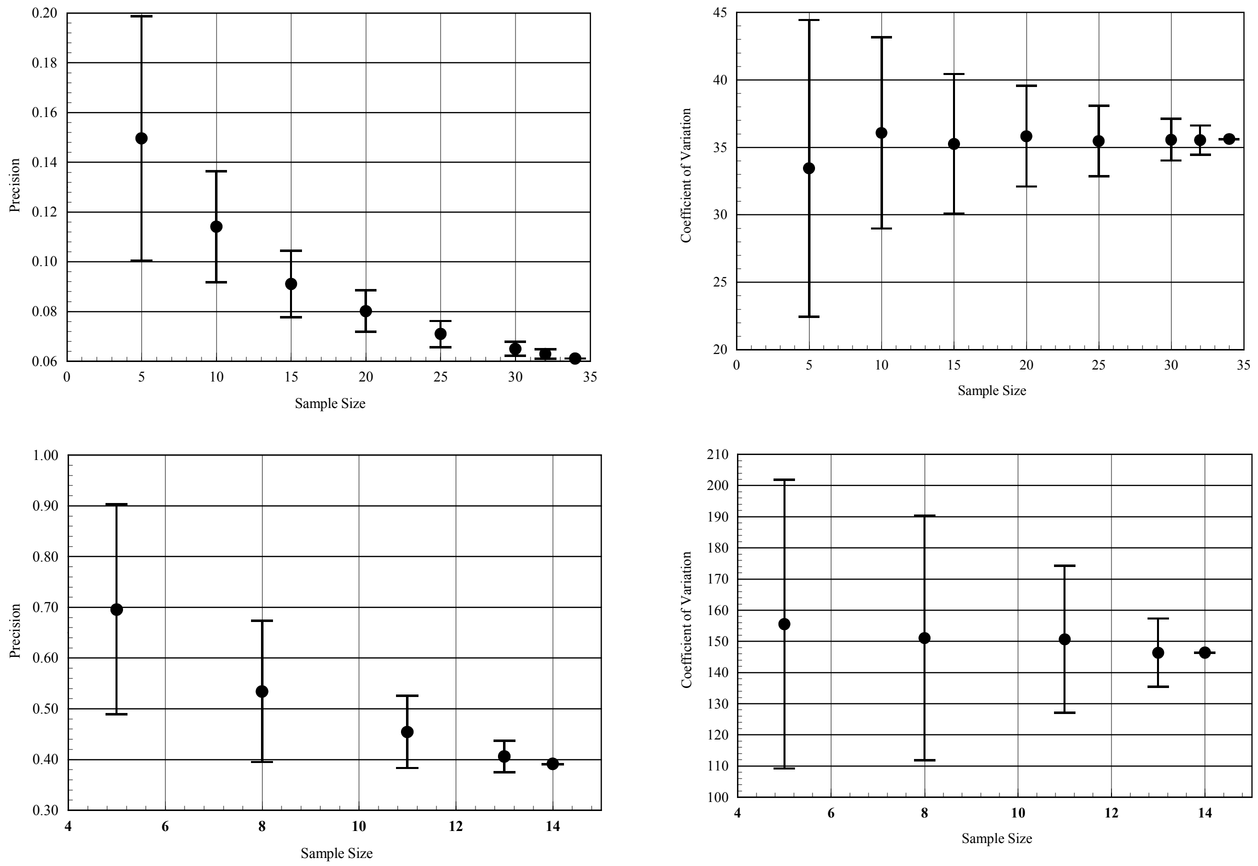


Fig. 7. Precision and coefficient of variation with increasing sample size for (*top*) the Reef Slope stratum, and (*bottom*) the Sand Stratum in the MMCA.

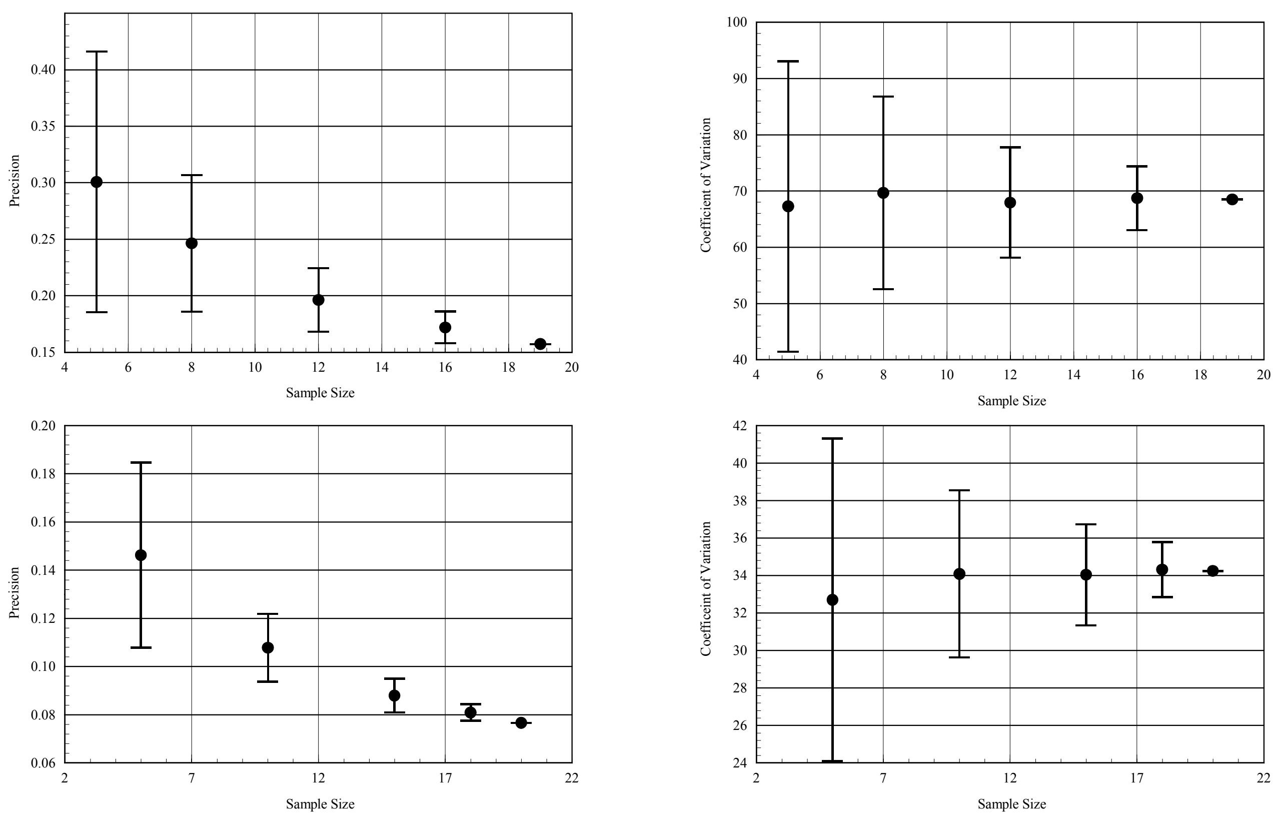


Fig. 8. Precision and coefficient of variation with increasing sample size for (*top*) the mixed stratum and (*bottom*) the Shallow Patch Reef stratum in the MMCA.

Table 3. Stratum estimates of coefficient of variation, sample size, and precision based on simulations.

STRATA			Precision	
MMCA	**CV**	**0.20**	**0.15**	**0.10**
Reef Slope	0.36	2	5	13
Deep Patch Reef	0.74	14	23	51
Shallow Patch Reef	0.34	2	5	12
Sand	1.46	48		
Mixed	0.69	12	20	41
SBFR				
Stratum 1	0.30	2	3	8
Stratum 2	0.33	2	3	8
Stratum 3	0.51	7	12	25

CONCLUSION

The aggregation of reef fish into broad categories can be assumed to influence determination of sample size, owing to the ecological variability of the species that comprise the categories. Samoilys and Carlos (2000) found relative comparability in precision stabilization with increasing sample size across five Families in a Great Barrier Reef study site. Analysis of precision and CV for the distinct categories from this study will provide further elucidation in determination of sample size.

Results of the abundance data from the MMCA 1999 survey reinforced the UVC paradigm that a limited number of highly trained personnel serve as fish counters, which also reflects the need for sufficient survey planning. Although the 1999 data set cannot be used in future trend analysis, the data set does serve as an example of how not to conduct an UVC, and therefore can provide future CNMI MPA managers and researchers with guidance. Categories that did not yield abundance estimates will be re-evaluated for exclusion from future survey work. Lutjanids and lethrinids will most likely be retained, because these have been numerically abundant in similar-sized transects in un-harvested areas of the NI, and are key food-fish species whose absence is indicative of fishing pressure (Trianni 1999).

With regard to the simulations, an interesting observation was the relative stability of the simulated CV mean for a stratum over increasing sample size. This behavior deviated from that presented by Samoilys and Carlos (2000), who found a decreasing trend of CV with increasing replication. The use of CV for comparing the relative variability between strata can aid in stratum determination, especially when coupled with precision results. These results will serve as a suitable template for further analysis of the CNMI nMPA survey data, which will guide further refinement of the survey methods.

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ESTABLISHING MARINE PROTECTED AREAS IN BRITISH COLUMBIA: AN NGO PERSPECTIVE

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Abstract

The marine campaign of the Canadian Parks and Wilderness Society is working for the establishment of a distinctive and representative network of marine protected areas in the marine waters of British Columbia (BC). BC's coastal and marine ecosystems are among the richest and most diverse in the world, yet the ecological balance in the sea is being threatened by human activities such as over-harvesting, pollution, habitat degradation, climate change and the introduction of alien species. The marine campaign is geared towards the designation of five marine protected area (MPA) sites – Southern Strait of Georgia, Gwaii Haanas, Scott Islands, Indian Arm, and Hecate Strait Sponge Reefs, in addition to Fisheries and Oceans Canada's (DFO's) MPA pilot sites. The Canadian Parks and Wilderness Society's approach is to advocate large zoned marine protected areas. It is developing an active constituency in BC's coastal communities and is increasing public and marine resource user support for marine protected areas, and works closely with communities surrounding its focal sites, First Nation peoples, fishermen, and others who have a particular interest in the regions. The paper expresses concern about the slow pace of progress on MPAs and discusses some of the key challenges and impediments to future progress.

Keywords: marine protected areas, MPAs, British Columbia, ocean conservation, Canadian Parks and Wilderness Society

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INTRODUCTION

Although more than 100 marine sites on the Pacific Coast of Canada have some type of legal designation, these sites represent only 1.25% of British Columbia's marine environment (Zacharias and Howes 1998). The scientific evidence supporting the need for fully protected areas is now conclusive regarding the benefits to marine biodiversity, yet on Canada's Pacific Coast less than 0.1% is fully protected. Clearly, much more work is needed to ensure adequate protection of British Columbia's ocean environment through the establishment of marine protected areas (MPAs) and marine reserves.

Momentum to designate MPAs in British Columbia (BC) has been building over the past few years within both levels of government, supported by the work of a number of non-governmental organizations. However, as is the case in the rest of Canada, progress in achieving actual designation of proposed sites has been very slow in BC. Significant results on MPAs will require political commitment, resources and staff, and greater public awareness and demand.

CANADA'S PACIFIC MARINE ENVIRONMENT

Canada's dramatic Pacific coastline is bracketed by snow-peaked mountains and thousands of islands robed in temperate rainforests. The shoreline is deeply indented with inlets and fjords, and the many river estuaries once supported large populations of Pacific salmon. Tidal jets in island passages stir up nutrients, supporting an exceedingly rich diversity and abundance of marine species, including plants, fish, invertebrates, birds and mammals. Excluding birds and mammals, there are more than 7500 known species of marine life in BC's marine waters. The economic well-being of British Columbia is tied to the health of the marine environment, which sustains important commercial fisheries, and provides a variety of recreation opportunities, including diving, sailing, and a burgeoning sea kayaking destination for local and international tourists. Urban development, log booming, and cruise-ship travel are some of the other uses of the marine environment in BC.

THREATS TO THE MARINE ENVIRONMENT IN BRITISH COLUMBIA

The wealth and diversity of life in British Columbia's marine environment have not been immune to the cumulative impacts of commercial and sport harvesting, pollution, habitat alteration and loss, coastal development, invasion by exotic species, and the effects of global warming

(Cannings *et al.* 1999). Specific examples of our misuse of marine species and the environment abound in BC: the demise of the sea otter early this century (Ministry of Water, Land and Air Protection 2003); the last humpback whale in the Strait of Georgia in 1907 (Wildwhales 2002); the temporary closure of the herring fishery in 1968 (Fisheries and Oceans Canada 2002a); the closure of the abalone fishery in 1990 (Fisheries and Oceans Canada 2002b); declines in salmon, herring, lingcod, inshore rockfish, and sea urchins; and the closure of 160 shellfish-growing areas (72,000 hectares) due to pollution (Environment Canada 2002).

Virtually all commercially valuable marine populations are now overexploited at least in part of their ranges, as are many others caught incidentally as bycatch (Botsford *et al.* 1997). We are now fishing lower trophic levels, or "fishing down the food web" (Pauly *et al.* 1998). For example, in the southern Strait of Georgia only 10% of the historical biomass of rockfish and lingcod remains (Martell *et al.* 2000). Other threats to the marine environment in BC include habitat destruction (including destruction from fishing gear), open-net cage farming of Atlantic salmon, pollution from land-based sources and dumping of pollutants by ships, proposed oil and gas exploration and development, and the introduction of invasive species (Cannings *et al.* 1999).

MARINE PROTECTED AREAS (MPAS)

Evidence from existing marine area closures indicates that marine reserves and protected areas will be effective tools for addressing conservation needs as part of integrated coastal and marine area management (National Research Council 2001). In February 2001, 161 leading marine scientists signed a consensus statement stating that marine reserves (no-take MPAs) are a highly effective but under-appreciated and under-utilized tool that can help alleviate the declining state of oceans and collapse of fisheries (NCEAS 2001).

MPAs are areas in the ocean that have long-term legal protection. MPAs include the seabed, water column, plants and animals and their habitats. MPAs can range in size, providing different levels of protection, from harvest refugia closed to all consumptive and possibly other human uses, to multiple-use areas allowing for human uses compatible with the conservation objectives.

MPAs, especially networks of no-take MPAs, can provide an array of benefits to marine ecosystems:

- MPAs can protect ecosystem structure and functioning by protecting habitats and communities from extractive activities (Murray *et al.* 1999);
- MPAs can benefit exploited marine populations and fisheries by increasing sizes, abundance, and spawning biomass of exploited populations (Bohnsack 1995);
- MPAs can increase our scientific understanding of the marine environment by providing for unexploited areas against which to measure change (Dayton *et al.* 1998);
- MPAs can enhance non-extractive human activities by creating social and economic opportunities dependent on minimally disturbed marine sites, such as wilderness experiences, scientific research, advanced marine education, diving, etc. (Murray *et al.* 1999); and
- MPAs can support fisheries and fisheries management by providing an insurance mechanism against failure of traditional fisheries management (Murray *et al.* 1999).

JURISDICTIONAL ARRANGEMENTS

A cooperative federal and provincial approach to MPAs is necessary in BC and the rest of Canada, given the shared jurisdiction over the marine environment. The federal government retains exclusive constitutional jurisdiction over the conservation and management of all organisms in the water column (including marine mammals, finfish and shellfish), as well as issues transcending international boundaries, navigation, marine pollution and migratory birds. The provincial government owns all coastal property above the low-water mark and the seabed within inland waters. In addition, First Nations have constitutional rights (section 35) to fish for food, social and ceremonial purposes (*Constitution Act* 1982), and through the British Columbia Treaty Negotiation process additional rights, jurisdictions and associated benefits and entitlements will be clarified (Government of British Columbia 2002).

DESIGNATION MECHANISMS

A number of legislative designation mechanisms exist to establish MPAs in BC, including:

- MPAs under the *Canada Oceans Act* (Fisheries and Oceans Canada 1996);
- National wildlife areas and marine wildlife areas under the *Canada Wildlife Act* (Environment Canada 1985);
- Migratory bird sanctuaries under the *Migratory Birds Convention Act* (Environment Canada 1994);

- National marine conservation areas under the *Canada National Marine Conservation Areas Act* (Parks Canada 2002); and
- Provincial marine parks under the *Parks Act* and provincial ecological reserves under the *Ecological Reserves Act* (Ministry of Water, Land and Air Protection 1996a; Ministry of Water, Land and Air Protection 1996b).

In addition, Fisheries and Oceans Canada can implement fisheries closures under the *Fisheries Act*, although such closures do not provide long-term legal protection and are not MPAs *per se*.

EXISTING MPA SYSTEM IN BRITISH COLUMBIA

British Columbia has 27,000 km of coastline, 6500 coastal islets, and 290,000 sq km of marine waters. Of this, about 1600 sq km, or less than 1% of BC's marine waters have some degree of protection, mostly concentrated in the coastal nearshore region. This 1600 sq km comprises

- 1 national park reserve (Pacific Rim), which has 21,390 hectares;
- 5 migratory bird sanctuaries and 1 national wildlife area totalling 2310 ha;
- 79 provincial parks with a marine component, totalling 124,323 ha – 34 of these are >200 ha and 30 of these have some fishing closures; and
- 15 provincial ecological reserves with a marine component, totalling 46,651 ha – 6 of these are >200 ha and only 5 have some fishing closures.

Even though the above areas provide some degree of protection, most have no active management programs or enforcement presence, and most do not prohibit fishing. In fact, <0.01% of BC's ocean waters are fully protected, prohibiting all extractive activities.

CHALLENGES AND IMPEDIMENTS TO PROGRESS ON MPAS

Progress on MPAs on the Pacific Coast, and across Canada, has been very slow. Although there seemed to be considerable momentum during International Year of the Ocean (1998), a number of issues are hindering or delaying the designation of new sites and the completion of policies and strategies that are critical to the establishment of a network of representative and unique MPAs in all of Canada's marine regions. These factors or issues are considered separately below, but there are obvious interrelationships between them, e.g. government funding has been a serious impediment to progress. New funding requires political support, and political support is often determined by the degree of public support.

FUNDING ISSUES

The lack of new funding, and significant budget cuts to the three federal agencies with MPA programs has been one of the most serious impediments to the establishment of MPAs.

Environment Canada

Environment Canada's legislation has the longest history, with the Migratory Birds Convention Act dating back to 1916 and the Canada Wildlife Act dating back to 1972 (with amendments for marine wildlife areas added in 1994), yet they have been facing serious financial issues for many years. In 1984, the Canadian Wildlife Service, which manages the sites protected by the above legislation, came to the end of its acquisition budget for new sites. Although the Service has 143 sites across Canada, totalling 11,600,000 ha and second only in extent to the national parks system in Canada, last year's total budget to manage these sites was $CAN1.9million or $0.16/ha. When compared with Parks Canada, which has $9.00/ha, or the US National Wildlife Refuge System at $US12.00/ha or the US National Parks Service at $US52.00/ha, the scarcity of financial resources is obvious (McLean 2002).

As a result, Environment Canada faces serious issues regarding its stewardship of existing sites: no active management; inadequate enforcement; unmaintained and inaccurate mapping; health and safety liabilities; doubtful protection of ecological integrity in many sites; and uncoordinated management of the collection of sites (McLean 2002).

In 1999, Environment Canada developed a marine protected areas strategy, which it was hoped would lead to the addition of new marine areas to their programs. However, the severe lack of resources has left no capacity for this program. Of the existing sites managed by Environment Canada, 69 include some part of the marine environment. The one new site they are actively pursuing is the Scott Islands proposed marine wildlife area off the northwest tip of Vancouver Island in BC (see later section).

Parks Canada

Although the National Marine Conservation Areas legislation is now finally in place, new funding for Parks Canada has not been forthcoming for either national parks or national marine conservation areas. In fact, since 1993, the department's budget has been cut by $CAN100million (Francoli 2002).

Parks Canada has deferred new proposals "…until adequate funding for planning, negotiations and subsequent development and operations can be provided" (Parks Canada Agency 2000). According to the Parks Canada Agency corporate plan for 2000–2005 (p. 23), $224million in start-up funds and $15million in annual operating expenses are required to develop the 8 national parks and 4 national marine conservation areas where feasibility studies or negotiations are planned or underway.

Fisheries and Oceans Canada

In 1997, Canada became the first country in the world to pass an Oceans Act. However, when the Act was passed, Parliament did not see fit to allocate new resources for its implementation. As a result, Fisheries and Oceans Canada, the agency with responsibility for its implementation, reallocated financial resources from its existing budget to allow for the establishment of an Oceans Directorate within the department and for a number of marine protected area and integrated ocean management pilot projects to begin across the country. Since June 1998 this has amounted to $63million or about $15million/year (Carson, pers. comm., August 2002).

A more recent initiative has been the development of the Canada Oceans Strategy, which outlines a comprehensive approach to implementation of the Oceans Act. The strategy was released in July 2002, and public information sessions are being aimed at getting public input on an action plan. Fisheries and Oceans Canada is also working with provincial counterparts across the country to develop an agreed action plan that while being national in scope will allow for regional flexibility in its delivery. Fisheries and Oceans Canada will likely go back to Cabinet in the next budget round to finally secure new funding needed to implement the Oceans Act.

POLITICAL WILL AND UNDERSTANDING

For more than 4 years, Parks Canada attempted to pass legislation that would allow for the establishment of national marine conservation areas, a companion program to the national parks program (Dunsmuir 2001). The Bill was introduced in Parliament three times, and was reviewed by a Parliamentary committee twice, before it finally received Royal Assent in June 2002. The absence of a strong political champion in federal government and broader Cabinet and caucus support for this legislation was the most significant factor delaying its passage.

Other issues also contributed to the delay, including the failure to convince local participants in Newfoundland that the proposed site in Bonavista Bay should go ahead (Lien 1999), and the decision by the Official Opposition, particularly its members from BC, to fight the bill due to their perceived lack of community consultation on the bill, their concern about duplication in federal programs, and their perception that the bill would prevent oil and gas development on the Pacific Coast.

Overall, these issues reflected the lack of understanding of marine protected areas on the national political scene. The opposition to the legislation also ignored the fact that of all the federal legislation available in Canada to establish marine protected areas, the *NMCA Act* most clearly outlines the process for identification, review and establishment of potential sites, gives clear direction to the Minister that local communities and interests must be consulted in the process, and requires the agreement of the provincial government. The Act also stipulates that NMCAs will be divided into zones that will allow for the continuation of sustainable resource use.

JURISDICTIONAL COMPLEXITY

With three federal MPA programs, more than 20 federal agencies with oceans responsibilities, and three provincial agencies with marine responsibilities, together with disagreements about ownership of the seabed in parts of the Pacific Coast, there can be no question that from a jurisdictional perspective MPAs are situated in a complex institutional environment. Although this situation has been recognized, and some steps taken to address this complexity, much more needs to be done.

In 1994 in BC, the federal and provincial government agencies with responsibility for the establishment of MPAs created an intergovernmental steering committee that developed a joint marine protected areas strategy for the province. This draft strategy, released in August 1998, outlines a coordinated and integrated federal and provincial government approach to marine protected areas in BC that includes the following: a definition of MPAs and their benefits; a vision for a system of MPAs that are representative of all marine ecosystems on the Pacific coast of Canada; goals for MPAs; potential management regimes, ranging from no-take or strict preservation areas to multiple-use areas; and a coordinated process for decision making on MPAs, from identification to evaluation to establishment and management (Government of Canada and British Columbia 1998). This strategy is a good approach and could serve as a model of clarifying jurisdictional complexity in other parts of Canada.

Public consultation on the strategy was completed some time ago. Unfortunately, the final strategy, together with an action plan and timelines for implementing the strategy, has not been released. Factors contributing to the delays in finalizing this strategy include the lack of a political champion at either level of government to push officials to complete the work, a provincial election, and the lack of support in the nation's capital for a regional approach to MPAs that might differ in some respects from the national approach being put forward by Fisheries and Oceans Canada.

The recently released Canada Oceans Strategy is an attempt to address ocean governance issues, including MPAs, both within the federal government, and between the federal government and provincial and territorial governments. An Oceans Task Group has been established by the Canadian Council of Fisheries Ministers to address these governance issues, but these discussions are at an early stage. It is critical within the context of Oceans Strategy implementation that Fisheries and Oceans Canada begin to play the role it was assigned in the Oceans Act – to facilitate the development of a national MPA strategy that would bring together the three federal agencies, as well as the provincial and territorial governments.

FIRST NATIONS ISSUES

The coastal First Nations of BC have always relied on the marine environment for resources essential for food, social and ceremonial purposes. In addition, their spiritual and cultural lives are tied to the oceans. Although few treaties have been signed with BC First Nations, the constitution guarantees their rights to fish for food, social and ceremonial purposes (*Constitution Act 1982*). During treaty negotiations in BC, new rights and control over land, sea and resources are being negotiated. In addition, other arrangements for joint management of protected areas are being discussed. Marine protected areas have been a traditional part of First Nations' management of the oceans, although they did not use this terminology. With the arrival of Europeans to North America, First Nations were deprived of their management responsibilities in a number of areas, including the oceans. Owing to some past negative experiences with the establishment of protected areas in their traditional territories without their consent, many First Nations are now suspicious of MPA programs.

In addition to giving their consent to new protected areas, First Nations expect to work in partnership with other government agencies in the management of protected areas, and they are also including protected areas in their treaties. For example, the Nisga'a First Nation treaty includes a commitment to establish a protected area in Observatory Channel, and the Heiltsuk are identifying a number of marine areas to be managed by the First Nation. Another approach is that of the Haida Nation, which is claiming title to both the land and sea in Haida Gwaii. The outcome of the Haida title case will set some important precedents in BC.

Discussions are also underway to develop a Memorandum of Understanding with First Nations through the BC Aboriginal Fisheries Commission, which would outline First Nations' roles in the Pacific MPA strategy and in the development of MPAs on the Pacific coast (Carson, pers. comm., 2002). As the situation at the proposed Race Rocks MPA is demonstrating, MPAs will not be established in BC without First Nations support, and this support will be contingent on a cooperative management approach that not all government agencies are prepared to implement. Development of individual MPAs must inevitably involve the local First Nations who may claim the area as part of their traditional territory.

PUBLIC AWARENESS

In 2001, CPAWS-BC commissioned a poll of BC residents to determine their knowledge of and attitudes toward marine protected areas. The responses showed strong public support for the creation of fully protected marine reserves where all extractive activities, such as fishing and dredging, are prohibited. Over 52% of respondents would favour establishing such reserves in their local area, knowing that this means they would no longer have access to recreational fishing in the same areas they used to.

The poll revealed that the present system of marine protected areas falls far short of British Columbians' expectations. When asked how much of British Columbia's ocean is fully protected from all extractive activities, respondents believed an average of 18% to be fully protected. But in fact, less than 0.01% of British Columbia's ocean is fully protected (Strategic Communications 2001). Although the public in BC is supportive of MPAs, their belief that so much of the ocean is already protected has led to some complacency among the public. If the public is to be mobilized in support of marine protected areas, additional educational efforts will be needed to make them aware of how little has been done to protect the marine environment, and to encourage them to do more to help. In the USA, in similar surveys, when respondents were told how little was actually protected (<1%), 75% felt that protection should be increased (Seaweb 1999).

FISHING INDUSTRY CONCERNS

The commercial fishing industry in BC is wary of MPAs and concerned about further limits on their access to fishery resources. The decline in many fish stocks has already created hardship for many local fishermen. There is still no widespread knowledge in the fishing industry about the potential fishery benefits of MPAs and the demonstrated benefits from MPAs elsewhere in the world. Recently, however, the United Fisheries and Allied Workers Union passed a motion at their annual meeting supporting MPAs with conditions, including the following: that rules must apply to all groups (including aboriginal, sports, commercial, etc.), and that fishermen are engaged in meaningful consultation so as to maximize the benefits to fisheries and minimize the costs (UFAW 2002).

The sportfishing industry is more opposed to MPAs than is the commercial sector, and it seems less willing that the commercial sector, even in the face of catastrophic declines in species such as rockfish and lingcod, to agree to limits on sportfishing opportunities, or to the establishment of MPAs (Symington, pers. comm. 2002). As a participant in the Race Rocks MPA pilot advisory board, the sport fishing representative was the most reluctant to agree to full fishing closures for the area.

CANADIAN PARKS AND WILDERNESS SOCIETY'S APPROACH

Over the past eight years, the Canadian Parks and Wilderness Society's (CPAWS') approach to advancing the MPA agenda in BC has been multifaceted and evolving, and it attempts to address the challenges and impediments to establishing MPAs. Initially, our work focused on the development of a policy framework for MPAs that encouraged the development of the federal/provincial strategy noted above, as well as encouraging other non-government organizations to support marine protected areas.

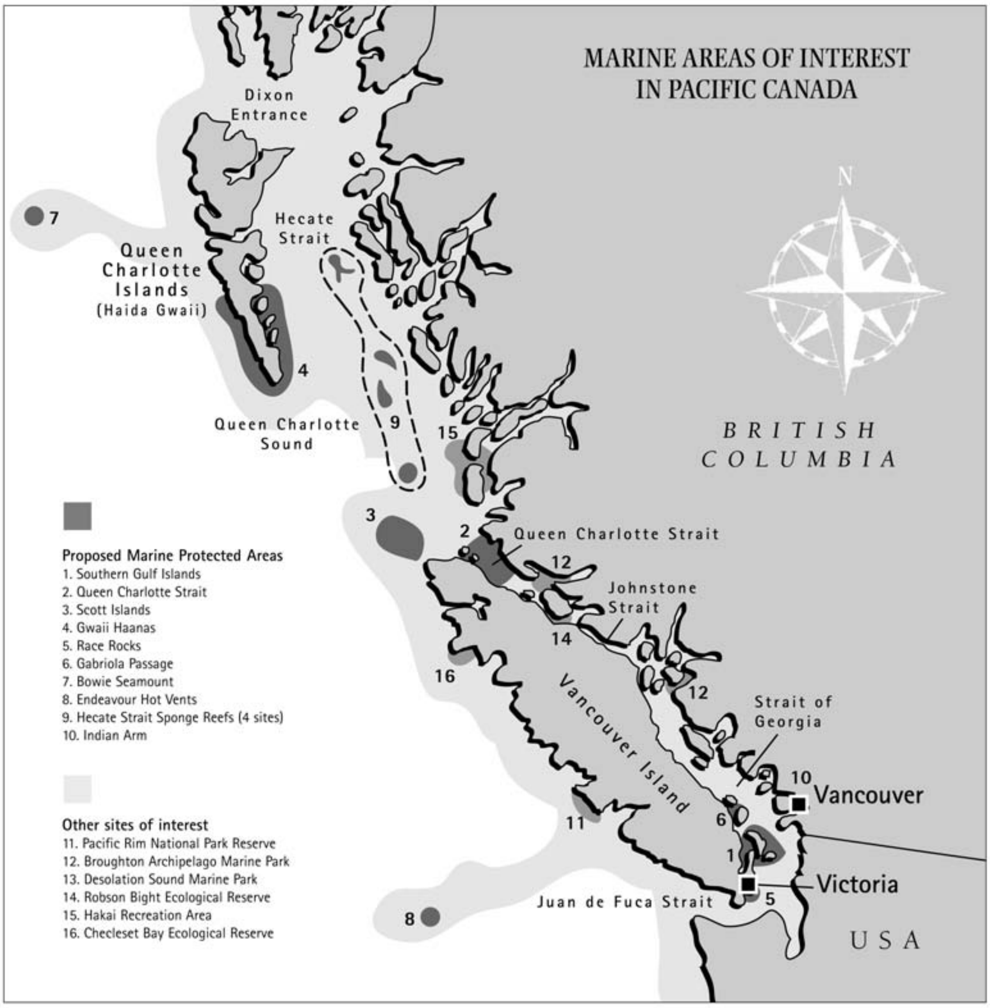

Fig. 1. Marine areas of interest along the British Columbia coastline.

While continuing to work on the policy framework, CPAWS catalogued, mapped, and reviewed potential MPA candidates for the entire BC coast. Using this information, we identified key campaign sites (Fig. 1) to anchor the representative and unique MPA network we were trying to achieve, and to allow us to demonstrate the application of large, zoned MPAs.

CPAWS has initiated projects aimed at developing community awareness and support for these campaign sites, and for MPAs in general. We have also added to our list of campaign sites in the face of emerging opportunities, such as the MPA pilot sites announced by Fisheries and Oceans Canada in June 1998 (Race Rocks, Gabriola Passage, Bowie Seamount, and Endeavour Hydrothermal Vents).

Community-level outreach and consensus building is a key focus for our work, while we continue to both pressure and collaborate with government agencies to achieve designation of the sites, and to complete the policy framework. More recently we have embarked on a larger collaborative program aimed at achieving a large-scale ecosystem vision on the Pacific Coast of North America, from Baja California to the Bering Sea (Jessen and Lerch 1999). In accordance with this larger ecosystem vision, CPAWS in cooperation with various government and nongovernment partners is also developing a Marine Conservation Features Map for the Pacific Ocean of Canada. This map will identify biologically significant areas in need of protection, while also delineating other marine areas of importance. We hope that this information will contribute to the integrated management projects required under the *Canada Oceans Act*.

SOUTHERN STRAIT OF GEORGIA

CPAWS began working in the Southern Strait of Georgia in 1997 for a number of strategic reasons. First, the site, between Vancouver and Victoria in the Strait of Georgia, is dotted with islands that are popular weekend and vacation destinations for city residents. Second, the "environmentally conscious" local islanders were already supporting local conservancies groups in order to protect the natural environments of the islands. Third, Parks Canada had identified this region as a potential national marine conservation area, and through a federal/provincial agreement, had garnered provincial government support for the establishment of a National Marine Conservation Area (NMCA) here.

The 1995 Pacific Marine Heritage Legacy program jointly announced by the federal and provincial governments committed to the establishment of a national park on the Gulf Islands and a national marine conservation area in the Southern Strait of Georgia (Canadian Heritage 1995). Three years later, in November 1998, the provincial minister and federal ministers announced that the national feasibility study on marine conservation areas would begin (Department of Canadian Heritage 1998). Unfortunately, this public study process did not begin, owing to events in other parts of the country.

In March 1999, the feasibility study process for another proposed NMCA in Bonavista Bay, Newfoundland, fell apart. Participants in the Bonavista Bay process withdrew their support in their presentation to parliamentary committee for Canadian Heritage while it was conducting hearings on the proposed NMCA legislation. With the legislation mired in controversy and the program itself being questioned, Parks Canada decided to ensure that two things were in place before embarking on any new sites: approved NMCA legislation and adequate levels of funding. This put a stop to any further plans to embark on either the Southern Strait of Georgia or the Gwaii Haanas sites (Lee, pers. comm. 2001). As CPAWS became aware that these financial and political constraints would indefinitely delay a process led by Parks Canada, our approach changed. While we continued to work to support the approval of the legislation and additional funding for Parks Canada, locally we encouraged groups to work with us to develop a consensus vision for the future NMCA.

In addition to encouraging and supporting the work of local conservancies on marine issues in the waters surrounding each of their islands, a key role for CPAWS has been to bring these groups, other supporters and interests, as well as other levels of government, together to encourage a collaborative effort to develop a vision for the entire Southern Strait of Georgia. The first product of this collaborative effort is a recently published brochure outlining the first components of our shared vision that has been distributed to all island households.

GWAII HAANAS

More than 200 km off the mainland coast of BC lies Haida Gwaii (Queen Charlotte Islands). The southern end of this island archipelago supports the most abundant and diverse marine community on the Pacific Coast of Canada. The rich sea life is an important source of food for millions of seabirds, bald eagles, and black bears.

In 1988, after years of controversy over logging in Haida Gwaii that reached the international stage, the federal and provincial governments agreed that no further logging would take place on South Moresby Island and that a national park would be established. Later, in 1993, a landmark agreement was signed by the Government of Canada and the Council of the Haida Nation which jointly established the Gwaii Haanas Haida Heritage Site and the National Park Reserve and which outlined the joint management arrangements (Archipelago Management Board 1996). This agreement also acknowledged the unresolved issues between the two governments, particularly related to title to the land and sea. The Haida have recently gone to court to resolve the issue of title to all of Haida Gwaii.

Both the federal/provincial and the Canada/Haida agreement contained provisions to establish a MPA surrounding the national park reserve (Government of Canada and Council of the Haida Nation 1993). In order to establish a MPA here, a first requirement was that the existing oil and gas leases be extinguished. In 1997, the four oil companies holding these leases relinquished them, and more recently the provincial government handed the seabed title to the federal government.

The leadership and initiative of the Haida is crucial to the designation and adequate protection of this site. However, since the agreement with the Canadian government was signed, the Haida people have been working to protect the rest of their island home from logging, to building their relationship with Parks Canada in the management of Gwaii Haanas, and to fighting unsustainable fisheries management practices, such as the herring fishery in Gwaii Haanas. This has left little time to pursue the marine area.

In addition to Haida leadership and initiative, establishment of the national marine conservation area in Gwaii Haanas requires a joint Haida/Parks Canada/Fisheries and Oceans Canada agreement on management and a public feasibility study, including development of a management plan. These will require funding and staff, but Parks Canada, DFO and the Council of Haida Nation are proceeding with these discussions to be ready to start the process once new funds arrive. A significant challenge will be changing the way that fisheries management is conducted – to move it from a species-by-species approach to an ecosystem approach that is focused on a specific area, namely the Gwaii Haanas marine area.

In partnership with World Wildlife Fund Canada, CPAWS has assisted the Haida with public education and outreach, intervening in the herring fishery, and providing information as needed or requested on fisheries and MPA issues. Our most recent collaboration is the publication of a poster that will be distributed to celebrate the 10th anniversary of the Gwaii Haanas agreement.

SCOTT ISLANDS

Situated off the northwest tip of Vancouver Island, and with nearly half of the total seabird breeding population in BC, the Scott Islands represent the most important site for breeding seabirds in the province. 55% of the world's Cassin's auklet population and 7% of the Rhinoceros auklet population make the Scott Islands their home. The productive marine environment surrounding the islands provides a critical foraging area for the seabirds, which feed on either plankton or fish throughout the surrounding ocean wilderness. The food supply in the region also supports other non-breeding seabirds, such as sooty shearwaters and black-footed albatross.

Scott Islands Provincial Park, established in 1971, includes the five islands together with the surrounding 1 km ocean area. Managed by BC Parks, public access to these islands is prohibited. The provincial park provides protection to the seabird nesting areas and the coastal feeding areas of local shorebirds.

Although the islands are protected, the ocean area, so critical to the conservation of many species, is not. Recent studies by the Canadian Wildlife Service and Simon Fraser University show that many seabird species forage in flocks up to 100 km offshore. Here they obtain the food critical to their survival and to the survival of their chicks. In 2000, following 3 years of campaign pressure from CPAWS, the Canadian Wildlife Service (CWS) began the first Marine Wildlife Area process in Canada at the Scott Islands. However, this process has experienced numerous delays due to the lack of staff capacity with CWS.

In a partnership with the Canadian Nature Federation, CPAWS is working closely with Canadian Wildlife Service managers and biologists throughout this process. We have produced an educational brochure and will be convening meetings with communities, First Nations, the fishing industry and others to develop a design for the MPA, including boundaries, and internal zoning.

Already there are encouraging steps being made with regard to marine conservation and protection in the region: the Pacific Halibut Advisory Board recently made the formal recommendation that all longline boats use seabird avoidance devices; parts of the Scott Islands marine region are now a "Rockfish Protection Area" in recognition of the biological importance of the area; and halibut fishermen, whose activities sometimes lead to rockfish bycatch, have in turn agreed to close the area to fishing as an additional precautionary strategy.

INDIAN ARM

Located within the boundaries of the Greater Vancouver area, Indian Arm is a fjord, receiving fresh water from the Indian River and experiencing restricted salt-water exchanges with the more coastal Burrard Inlet. The marine environment of the Indian Arm marine region has, as with adjoining terrestrial lands, experienced significant impacts due to over-exploitation of resources and fragmented management. The ecological benefits of an MPA at Indian Arm include offering an opportunity for the restoration of marine areas disturbed by human activities and the recovery of groundfish and shellfish species, while also protecting migration corridors and important life-stage habitats (Lerch and Symington 2001).

Indian Arm forms the heart of the traditional territory of the Tsleil-Waututh Nation, who, concerned about the ecological health of the inlet, approached CPAWS in 1999 to jointly work on the conservation of the marine environment in Indian Arm. In May 2000, CPAWS and the Tsleil-Waututh Nation signed a Protocol Agreement, outlining shared values and detailing cooperative action on marine conservation in the Indian Arm region. Following a period of joint documentation of marine conservation values, we are now prepared to embark on a planning process for Tsleil-Waututh stewardship of the region, one that will apply both traditional and current marine management techniques including MPAs. The opportunity to establish an MPA in Pacific Canada in collaboration with a First Nation government is unprecedented in BC and offers immeasurable benefits to both marine and terrestrial ecosystems.

HECATE STRAIT SPONGE REEFS

The BC coast is the only place in the world where rare colonies of glass-like sponges are found. Dating back over 10,000 years to the last ice age, these sponges have formed extensive reefs in Hecate Strait between mainland BC and Haida Gwaii (the Queen Charlotte Islands). The four separate colonies cover between 150 and 300 square miles and are found at depths of up to 230 m. The origin of these sponges dates back to the Upper Jurassic period 140million years ago, when sponge reefs stretched from Portugal to the Black Sea (Conway *et al.* 2001; Krautter *et al.* 2001).

Studies over the past few years by Canadian and German researchers have shown that these rare and fragile reefs have been damaged by trawl fishing gear. As a result of their research, the trawl fleet had agreed to a voluntary closure to fishing for all four reefs. Unfortunately, the inadequacy of the voluntary measures was demonstrated by the discovery of extensive new damage to the most pristine of the four reefs during a research cruise by scientists this summer (Conway, pers. comm. 2002).

For over a year, CPAWS-BC has been requesting that Fisheries and Oceans Canada institute long-term legal measures to protect the reefs. In a meeting last year with the Fisheries Minister, CPAWS called to his attention the evidence from scientists that all four sponge reefs had been damaged by trawling. He committed to ensuring that no further damage would occur to the reefs (Dhaliwal, pers. comm. 2001). It is a tragedy that it was not until new damage was discovered in June of 2002 that Fisheries and Oceans Canada finally closed all four reefs to trawling.

The trawl ban under the *Fisheries Act* was an important first step, and the Minister committed in writing to consider the reef sites as potential MPAs under the *Oceans Act.* CPAWS-BC is actively pursuing this commitment in order to provide the longer-term measures for providing permanent protection for these unique marine features. We hope that the fishing industry will continue to cooperate in the development of MPAs to protect these important features for future generations.

OTHER SITES AND OPPORTUNITIES – MPA PILOT SITES

In August 1998, David Anderson, then Minister of Fisheries and Oceans, announced two MPA pilot sites, Race Rocks and Gabriola Passage. This was followed in January 1999 with an announcement of two offshore MPA pilot sites, Bowie Seamount and Endeavour Hydrothermal Vents. Preliminary meetings have been held on all four sites, and development of MPAs at Race Rocks and Endeavour Hydrothermal Vents are close to completion. CPAWS is a member of the Race Rocks Advisory Board, and has participated on consultations on Bowie Seamount and Endeavour Hot Vents. However, the Race Rocks and Gabriola Passage proposals are mired in First Nations issues that are resolvable given a more open, flexible and cooperative approach.

CONCLUSION

In September 2002 at the World Summit on Sustainable Development in Johannesburg, the Prime Minister (PM) of Canada pledged to create five new National Marine Conservation Areas in the next few years. This announcement came closely on the heels of the PM's decision to retire in 2003, and is said to be part of the PM's legacy package. At the time of writing, the speculation in Ottawa is that a funding announcement to support this commitment will be made in October 2002 (Francoli 2002).

Although there is a measure of relief and excitement about this announcement, it remains to be seen whether this new attention on environmental issues will also translate into real political and financial commitment to both the Canada Oceans Strategy, which is looking again to funding in the upcoming federal budget, and to the other MPA programs run by Environment Canada.

Although it appears that the issues of political commitment and funding are beginning to be addressed by the federal government, we remain concerned that the importance of First Nations in the MPA process is still not understood and appreciated within both government agencies and the public. As a result, there is a reluctance to engage in the kind of cooperative management approaches being sought by First Nations – ones that we believe will result in better MPA management, and the increased use of MPAs in marine conservation programs.

The process of establishing MPAs has been painstakingly slow in British Columbia. However, we continue to be optimistic that, with enough pressure from nongovernmental organizations and the public, we can make significant progress in the coming years. The oceans are counting on all of us.

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LEGAL FRAMEWORK AND ENFORCEMENT EXPERIENCE OF MARINE PROTECTED AREAS IN TASMANIA, NEW SOUTH WALES AND COMMONWEALTH WATERS

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Abstract

With the exception of the Great Barrier Reef Marine Park, there have been no prosecutions for specific offences within marine protected areas (MPAs) in Australia at the federal level or in Tasmania and New South Wales. However, it cannot be assumed that compliance is responsible for this lack of prosecutions. Rather, in some cases, enforcement officers prosecute offences under more general provisions found in fisheries legislation than under provisions for specific offences created in MPAs. In other cases, there has been a long lag time between the declaration of MPAs and the adoption of comprehensive and effective legislative arrangements creating offences for specific activities within them. Hence, there may be periods during which MPA regimes fail to give adequate legal support to the environmental objectives they seek to achieve, partly because of the need to 'phase out' existing fishing activities. Additionally, they may fail to prohibit inappropriate activities immediately adjacent to MPAs. This paper examines the legal regimes that exist to establish MPAs in Tasmania, New South Wales and areas under federal jurisdiction and the offences recognised to ensure the protection of ecological values. Those analysed are regimes set up under 'umbrella' MPA Acts, site-specific Acts and other legislative arrangements using existing fisheries legislation. It is concluded that a legislative system allowing the award of modest rather than severe penalties would increase the likelihood of prosecution and would complement educative measures aimed at ensuring compliance.

Keywords: Legislation, regulation, marine protected areas, prosecution, jurisdiction

INTRODUCTION

The use of marine protected areas (MPAs) as a tool for marine resource management has gained momentum in Australia since the early 1990s. Their development was accelerated in the late 1990s following their inclusion as a core component of Australia's premier policy document for offshore areas – the 1998 Oceans Policy. With the enactment of marine park legislation in Victoria in June 2002, all sub-national jurisdictions and the federal government now have the capacity to declare MPAs under legislation. The rapid development in recent years of legal and institutional measures to establish and manage MPAs is remarkable in the context of the typically piecemeal development of measures to advance environmental policy in Australia. However, Australia's MPA experience has not been without controversy. A number of marine stakeholders, most notably some commercial fishers, have expressed concerns about the rationale for MPAs, the methods by which they are established, their effectiveness in meeting their conservation objectives and the lack of adequate measures to compensate existing users of areas within MPAs.

In large part, the establishment of MPA regimes in Australia reflects the high level of awareness among marine stakeholders and the community generally of the interlinked nature of human activities and their effects on marine ecosystems. The community has a broad expectation of ecosystem-based management approaches for marine areas rather than individual stock-maintenance approaches for commercial and threatened species. A corollary of this expectation is the need for demonstrable ecologically sustainable resource management practices (see Potts and Haward 2001). There is growing community interest – in particular among those marine stakeholders who are directly affected by the establishment of MPAs – in determining whether MPAs meet their multifaceted objectives. This paper responds to this need in small part with respect to Commonwealth (federal), New South Wales and Tasmanian MPAs. It examines the effectiveness of the legal regimes within those jurisdictions by focusing on the specific activities prohibited within MPAs and the record of prosecutions for such offences.

BACKGROUND TO MPAS IN AUSTRALIA

The impetus for the establishment of MPAs owes much to the recognised need to limit or mitigate the effects of commercial – and to a much lesser extent, recreational – fishing on marine and coastal ecosystems. MPAs have been promoted largely as a means of conserving resident fish stocks, with benefits of increased stock numbers and ecosystem integrity being expected to flow into adjacent areas. For example, the definition of MPAs adopted by the Australian Bureau of Rural Sciences underscores their perceived role primarily as a fisheries management tool: 'Marine reserves are spatially defined areas of ocean or estuaries where natural populations of marine species are protected, either in part or completely, from exploitation or other detrimental anthropogenic pressures' (Ward *et al.* 2001). To this end, fishers typically consider MPAs to be 'no-take' reserves in which the taking of any living marine resources is prohibited. However, it is common for MPA regimes to allow for the issue of research permits for the extraction of some natural resources as well as limited recreational and sometimes commercial fishing activity. Nevertheless, strict 'no-take' reserves may be declared for individual MPAs or for specific areas within larger MPAs.

There are countless differing definitions of MPAs. Some explicitly or implicitly emphasise their role in assisting in the management of exploitable resources. For example, the US National Academy of Sciences defines MPAs broadly as 'areas designated for special protection to enhance the management of marine resources' (National Academy of Sciences 2001). Other definitions emphasise their role in protecting representative areas of marine ecosystems. For example, MPAs have been defined in Victoria, Australia, as 'areas established to protect a sample of Victoria's marine plants and animals and their habitats' (Department of Natural Resources and Environment 2002). Despite some concern about the utility of MPAs for fisheries management, their perceived primary role as a fisheries management tool has been expanded in most Australian jurisdictions in recent years to encompass the fulfilment of more general marine ecosystem management objectives. Article 8 of the 1992 UN Convention on Biological Diversity, which provided much of the impetus for the development of MPAs, provides that State parties 'shall, as far as possible and as appropriate', establish a system of protected areas 'to conserve biological diversity'. Although the Convention is not specific with regard to terrestrial or marine environments, it is important to note that the objectives of protected areas are to conserve biodiversity. This is a broader and more challenging objective than simply the conservation of exploitable renewable resources such as commercial fish species. In Article 8(e) the Convention also envisages that areas adjacent to protected areas should be managed in such a way that they further the protection of protected areas. The role of MPAs in the Australian context has come to be that of protecting specially identified areas of the marine environment for their intrinsic worth rather than more narrowly that of propagating commercially exploitable fish species.

In addition to the creation of specific offences for certain activities within MPAs, a number of general principles are used for their management. These stem from the 'ecologically sustainable development' (ESD) concept and its attendant principles. ESD has been established as the principal policy platform for all decisions relating to the environment at the national, State and local government level since the adoption of the Intergovernmental Agreement on the Environment in 1992. The Australian and New Zealand Environment and Conservation Council (ANZECC) Task Force on Marine Protected Areas reported in 1999 that the development of MPAs in Australia is an illustration of the application of ESD. The Task Force envisaged, in relation to whether activities could be allowed within MPAs, that such decisions should be based on not compromising biodiversity conservation values, and hence that principles of ecological sustainability must apply. In relation to the crucial issue of whether commercial fishing activities could be permitted within MPAs, the Task Force noted:

> "The management arrangements developed for individual MPAs may require higher standards of management of resource use than may otherwise apply to the use or activity. This may be required so the activity does not compromise the primary goal of the MPA. A commercial fishery that is managed generally in accordance with ecologically sustainable development principles could be allowed within the MPA but may be subject to more comprehensive management arrangements; for example, arrangements relating to gear type or catch limits (ANZECC Task Force on Marine Protected Areas 1999: 32)."

Although MPAs are the most detailed and comprehensive measure available to protect areas of the marine environment, they are not the only management tools available. There is a complex array of federal and State legislative and institutional measures to protect Australia's marine environment. In particular, there is a broader body of fisheries regulations that operate in all marine areas, including MPAs. At the federal level, the most significant piece of legislation is the 500+ page *Environment Protection and Biodiversity Conservation Act* 1999 (Cth) (EPBC Act) administered by Environment Australia. In addition to this, there are the fisheries management activities of various government departments and agencies.

Process for the establishment of MPAs in Australia

ANZECC established a National Advisory Committee on Marine Protected Areas in 1992 (The Natural Resource Management Ministerial Council has since replaced ANZECC). The Committee was charged with the responsibility of coordinating the development of a National Representative System of Marine Protected Areas (NRSMPA) to expand the existing system of marine parks and reserves. In 1997 the Committee became a Task Force on Marine Protected Areas, which developed a Strategic Plan of Action to establish the NRSMPA. In 1998 the federal government reaffirmed its commitment to establishing a representative system of MPAs by including a commitment to their creation in Australia's Oceans Policy and establishing it as a key task of regional marine planning (National Oceans Office 2002).

MPAs are identified and declared by federal and State governments in their jurisdictions independently from each other, although it has always been intended that management responsibilities would be determined after consultation between the federal agency and the State concerned. The States are able to declare MPAs up to three nautical miles offshore following the grant to them of legislative competence in this area in the Offshore Constitutional Settlement of 1979. The only exception is the Great Barrier Reef Marine Park, which was established earlier under the *Great Barrier Reef Marine Park Act* 1975. The federal government may declare MPAs outside three nautical miles but within federal waters (to a maximum of 200 nautical miles), subject to obligations under the United Nations Law of the Sea Convention respecting navigation, and possibly fishing, rights of foreign-flagged vessels. MPAs may also be established and managed jointly, as envisaged in the Offshore Constitutional Settlement documents:

> "Where an area proposed as a marine park or reserve lies across the boundary of the territorial sea, the State concerned would establish that portion within the outer limit of the territorial sea under State legislation and the Commonwealth [Australian federal government] would legislate for that portion seawards of the outer limit of the territorial sea. Such arrangements would be subject to agreement between the State concerned and the Commonwealth on policy, planning and management for the whole area (Attorney General's Department 1980: 12)".

In this situation both governments use complementary legislation with cooperative management arrangements to establish MPAs (such as Ningaloo Marine Park, Solitary Islands Marine Park and Lord Howe Island Marine Park).

Of the seven sub-national jurisdictions in Australia that possess coastal areas, only New South Wales and Queensland have specific marine park legislation (see *Marine Parks Act* 1997 (NSW) and *Marine Parks Act* 1982 (Qld)). Other jurisdictions, such as Tasmania, Western Australia, the Northern Territory and Victoria, are able to establish MPAs under broader pieces of environmental legislation (see *Living Marine Resources Management Act* 1995 (Tas), *Conservation and Land Management Act* 1984 (WA), *Territory Parks and Wildlife Conservation Act* 1979 (NT) and *National Parks Act* 1975 (Vic)). A legal framework for the establishment of MPAs in South Australia will be based on a review of existing provisions under a number of pieces of legislation.

There has been much interest in expanding the establishment of MPAs in Australia, yet little attention has been devoted to evaluation of the effectiveness of MPA management (with the exception of their expected benefits for commercial fish species) (Hockings 2000; Houde 2001; Alder *et al.* 2002). In particular, the legal regimes for MPA creation have received scant attention. Notwithstanding this, determination of the effectiveness of MPA legislative models is not without its difficulties due to the great variance in regulations in protected zones, challenges for enforcement and the short history of MPAs.

LEGAL BASIS FOR MPAS IN FEDERAL WATERS, NEW SOUTH WALES, TASMANIA AND VICTORIA

Federal waters

The landmark EPBC Act is the federal government's omnibus environmental legislation. It replaced five much older pieces of environmental legislation – including the *National Parks and Wildlife Conservation Act* 1975 (under which Commonwealth MPAs were formerly established) – and covers numerous areas of environmental protection. Among other things, it sets up different types of protected areas. These are World Heritage properties, Ramsar wetlands, biosphere reserves, federal reserves and conservation zones. It also provides additional protection of marine areas by means of its strategic assessment requirements for fisheries (ss.146–154), the creation of criminal and civil fisheries-related offences (e.g. ss.23, 24A and 254) and the establishment of the Australian Whale Sanctuary in virtually all Australian waters (s.225). Six World Heritage properties extend to marine areas. These are Heard and McDonald Islands, Macquarie Island, Lord Howe Island, Shark Bay, Fraser Island and, most notably, the Great Barrier Reef. Federal reserves are the main tool by which the federal government can declare protection measures for areas of the marine environment. They may apply only to areas of the marine environment under federal jurisdiction or areas outside Australia that the federal government has international obligations to protect with respect to biodiversity or heritage (s.344(b)(ii)). The surface of coral formations and the subsoil of seabed are specifically included within federal reserves in areas of sea (s.345).

Section 347 EPBC Act provides, among other things, that federal reserves should be managed in accordance with the Australian IUCN (World Conservation Union, formerly known as the International Union for the Conservation of Nature) reserve management principles. Section 346(1)(e) provides that federal reserves must be assigned to one of the following categories:

- strict nature reserve;
- wilderness area;
- national park;
- natural monument;
- habitat/species management area;
- protected landscape/seascape; or
- managed resource protected area.

Activities listed under s.354 are prohibited in a federal reserve except where they are in accordance with an operational management plan. For marine areas, prohibited activities relate principally to killing, injuring, taking, trading, keeping or moving a member of a native species (s.354(1)(a)) or undertaking commercial actions. The civil penalty for individuals is $A550,000 and $5,500,000 for corporations. Mining operations are generally prohibited within federal reserves (s.355(1)). Regulations may also be issued to regulate or prohibit a large range of other activities for specific federal reserves. These include the power to regulate or prohibit in a reserve the following:

- pollution of water that is likely to be harmful to biodiversity: s.356(1)(a)(i);
- tourism: s.356(1)(b);
- access by persons or classes of persons: s.356(1)(e);
- the carrying on of any trade or commerce: s.356(k);
- the use and passage of vessels: s.356(p);
- the landing, flying and use of aircraft: s.356(q);
- the taking into and use of fishing apparatus: s.356(u); and
- the laying of baits and the use of explosives and poisons: s.356(v).

There is also a more general power to regulate the conduct of persons in federal reserves (s.356(j)).

In addition to federal reserves, the EPBC Act provides for the declaration of conservation zones for areas outside federal reserves. The purpose is to protect biodiversity in the area while it is being assessed for inclusion in a federal reserve (s.390D). A wide range of activities may be regulated in conservation zones (s.390E). Although previous usage rights in relation to land and seabed are protected within federal reserves (s.359(1) and conservation zones (s.390H), usage rights (see s.350(7) and s.27) in marine waters are not protected. Hence, previously held fishing licences and permits would not be protected in federal reserves or conservation zones.

The EPBC Act also protects listed species and communities through the creation of punishable offences for persons who (without authorisation) recklessly or non-recklessly (i.e. strict liability) kill, injure, trade, take, keep or move a member of a listed threatened species or ecological community in a federal area (including a Commonwealth marine area) (ss.196–196E). Similar offences are created for listed migratory species (ss.211–211E), listed marine species (ss.254–254E) and whales and other cetaceans (ss.229–230). Wildlife conservation plans may be made for listed marine species (s.285). A number of marine species are listed for special protection under s.248 (seasnakes, seals, crocodiles, dugong, turtles, seahorses, sea-dragons, pipefish, penguins, albatross and other birds). It is an offence to take, trade, keep or move a member of a listed marine species without approval (ss.254B and 255). Further, Regulation 8 of the EPBC Regulations 2000 establishes a caution zone around all cetaceans which means that a vessel must slow to a no-wake speed 300 m away from a cetacean unless the cetacean approaches the vessel. Exclusion zones can also be established whereby vessels are prohibited from approaching within 100 m of a whale and within 50 m of a dolphin.

Great Barrier Reef Marine Park

The Great Barrier Reef Marine Park is managed under a system of management and zoning plans and a permit system for commercial activities. Marine sanctuaries (commonly called 'green zones') have been declared within the marine park, covering 4–5% of the park. Snorkelling, diving, sailing and swimming are allowed in green zones yet any taking of plants or animals is prohibited. The focus of surveillance by Parks and Wildlife Officers is on inshore closed-area trawling and netting and remote offshore areas when illegal fishing frequently occurs.

Regulations have been issued under the *Great Barrier Reef Marine Park Act* 1975 (Cth) providing for penalties for offences. These range up to $A22,000 for an individual who enters or uses a zone for a purpose other than that permitted in a zoning plan. Owners of vessels may be liable for penalties up to $220,000 or $1.1 million where the owner is a company (see s.38MC; GBRMPA 2002c). Penalties up to $1,100 may be issued for breaches of the regulations. For example, s.13B(2) of the Great Barrier Reef Marine Park Regulations 1983 (as amended) provide that fishing (with the exception of fishing for research purposes) is prohibited in Habitat Protection Zones. Also, by way of example, a person who, in the absence of approval, uses an underwater breathing apparatus that is not a snorkel for non-scientific-research spearfishing in an unzoned area is liable to a penalty of $1,100 (s.38). Further, s.40(1) provides for a penalty of $1,100 for a person who takes, or has in possession, a fish of a listed species that is more than 1200 mm in length. At present, only three species are so listed: potato cod, estuary or greasy cod and giant groper (Schedule 5).

Where an inspector believes a prosecution to be in order, the matter is passed by way of a brief of evidence to the federal Director of Public Prosecutions (DPP) to determine whether the matter warrants prosecution. As with all criminal prosecutions, the decision of the DPP is made after consideration of matters such as the seriousness of the offence, the availability of sufficient evidence, whether a conviction is likely and whether prosecution is in the public interest. Inspectors may issue written warnings to alleged offenders in the event that the DPP does not prosecute. The GBRMPA prioritises matters for enforcement on three levels. High priority is assigned to matters arising from complaints from the public substantiated by evidence, or where large-scale environmental damage or depletion of natural resources has occurred or is likely to occur. Medium priority is assigned to matters where 'significant environmental damage has occurred or may occur, where financial reward or gain from an offence may exist or where significant management principles are disregarded' (GBRMPA 2002a). Low priority is assigned to minor or technical offences or where environmental damage is not likely to occur. The enforcement process involves risk assessment of illegal activities and detailed guidelines for prosecution.

Tasmanian Seamounts Marine Reserve

In 1999 a large reserve was declared under the *National Parks and Wildlife Conservation Act 1975* (Cth) approximately 170 km south of Hobart; its purpose was to add a representative sample of a seamount region to the NRSMPA and to protect the high biodiversity values of the seamount benthic communities from human-induced disturbance. On 26 June 2002 a management plan under the EPBC Act came into effect. The reserve provides a novel vertically zoned protected area. Access to the Highly Protected Zone below 500 m is prohibited, whereas the upper 500 m is classified as a Managed Resource Zone. Fishing can be permitted in this area such as for pelagic species (e.g. tuna longlining). It remains to be seen whether the boundary at 500 m below the surface can be enforced to protect the lower portion from weighted longline fishing, deep purse-seine fishing and deep trawl fishing. Onboard monitors appear to be the only feasible method for ensuring compliance.

Tasmania

The first formal protection of a coastal area in Tasmania was in 1916 when Freycinet National Park was declared by government gazette. The first marine reserves were declared in the south and east of the State in 1991 in accordance with the Tasmanian Government's marine conservation strategy. These were the three small reserves of Tinderbox, Governor Island and Ninepin Point and the larger area near Maria Island. In addition to these MPAs, there is a Restricted Fishing Area at Crayfish Point in the Derwent River. There are also Ramsar listed sites including the 0.1 hectare Moulting Lagoon Game Reserve near Bicheno on the east coast.

The development of the policy process and legislative framework for Tasmanian MPAs has been complex (Kriwoken and Haward 1991). It has been only very recently that a transparent and integrated approach to the identification and selection of MPAs has been adopted. Kriwoken and Haward (1991) reported that the initial debate in the late 1980s concerning proposals for MPAs in Tasmania was fuelled by increasing concern about declining marine quality due to overfishing, waste dumping and sewage outfalls. Significantly, the rapid development of the salmon aquaculture industry had the effect of galvanising support of diverse interest groups for MPAs. Some boating and fishing users of the coastal zone (who could have been expected to oppose MPAs) generally supported them in the face of a possibly larger threat posed by aquaculture operations – the threat of reduced access to marine areas in terms of boat anchorages and cruising waters. Hence, some of the initial support for MPAs in Tasmania may have owed more to 'desire to restrict an alternative policy direction' than ecological objectives (Kriwoken and Haward 1991).

A new comprehensive strategy for declaring MPAs was released in 2001. Under Tasmania's Marine Protected Areas Strategy, the Resource Planning and Development Commission (a statutory authority established to oversee State planning and environmental issues) undertakes identification and selection of new MPAs. It may then recommend to the Minister for Primary Industries, Water and Environment the establishment of new MPAs that are then to be approved by Cabinet. The Commission is currently assessing Port Davey/Bathurst Harbour in the south-west of the State and the Kent Group of Islands in the north of the State. The primary goal under the Strategy of MPAs is, in addition to establishing and managing a representative system of MPAs, to 'contribute to the long-term ecological viability of marine and estuarine systems, to maintain ecological processes and systems, and to protect Tasmania's biological diversity' (Department of Primary Industries, Water and Environment 2001). The Tasmanian definition of MPA is 'an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means' (Department of Primary Industries, Water and Environment 2001). Part of the significance of the new strategy lies in its emphasis on establishing a representative system of reserves rather than on protecting individual sites.

Tasmania's MPAs are established through the joint application of the *Living Marine Resources Management Act* 1995 (Tas) (LMRM Act) and the *National Parks and Wildlife Act* 1970 (Tas) (NPW Act). The objectives of the LMRM Act 1995 include the promotion of the sustainable management of living marine resources and the protection of marine habitats (Preamble). Under this Act (Part 5), marine resources protected areas can be established. Marine plants and animals can be protected and fishing activities such as netting can be regulated in restricted fishing areas and shark nursery waters. The purpose of the NPW Act is to establish and manage reserves with respect to the conservation and protection of the fauna and flora (Preamble). The NPW Act provides that 'nature reserves' or 'private sanctuaries' can be declared for 'land'. However, there is an expansive definition of land that includes 'land covered by the sea or other waters, and the part of the sea or those waters covering that land' (s.3(1)). Notwithstanding this, the Act cannot be used to protect fish or control fishing activities; thus, MPAs need to be established in terms of both legislative tools (see Department of Primary Industries, Water and Environment 2001). Hence, MPAs are declared under the NPW Act yet the marine resources are protected under the LMRM Act.

The LMRM Act provides in s.113 that a person who contravenes or fails to comply with a provision of a marine resources protected area is liable to a penalty of up to $550,000. Section 131 provides a penalty of up to $110,000 for a person who, in a marine resources protected area, engages in an activity that is likely to have a detrimental effect on its environment – except with approval or in accordance with a management plan.

New South Wales

NSW was the second State to enact specific marine park legislation. The *Marine Parks Act* 1997 (NSW) commenced operation on 1 August 1997. It established a specific authority to manage marine parks in the State – the Marine Parks Authority. The Marine Park Regulations 1999 came into effect on 1 March 1999. They provide for the development of zoning plans for 'sanctuary zones', 'habitat protection zones', 'special purpose zones' and 'general use zones'. Sanctuary zones provide the highest level of protection 'for biological diversity, habitat, ecological processes, natural features and cultural features (both Aboriginal and non-Aboriginal)'. It is intended that they provide opportunities for scientific research and 'recreational, educational and other activities that do not involve harming any animal or plant, or cause any damage to or interference with natural or cultural features or any habitat' (clause 6). The legislation provides that on-the-spot fines in the order of $300 to $500 may be issued for various offences. Alternatively, the offences may be prosecuted in court and attract a penalty of up to $11,000. Examples include the penalty of $500 for persons who without consent harm or attempt to harm any plant or animal or damage or attempt to damage habitat within a sanctuary zone (clause 7/Schedule 2) and the penalty of $500 for skippers who anchor or moor vessels in non-designated areas (clause 9/Schedule 2). Limited fishing is permitted in habitat protection zones (clause 12). Broader offences are created, including the penalty of $500 for the following:

> A person who, while in any part of a marine park, is in possession of any equipment (including fishing gear) that is used, or is designed to be used, for the purposes of taking an animal or plant is guilty of an offence if the taking of the animal or plant in that part of the park, at that time, is prohibited by or under this Regulation (clause 19(2)/Schedule 2).

A defence can be established by the defendant if he or she 'satisfies the court' that

> the equipment…was being transported, in accordance with the written approval of the Authority, to any place where the person could lawfully use the equipment… to take animals or plants, or…the equipment concerned was in a state in which it could not have been used…(clause 19(3)).

It is also an offence (penalty $300) to 'take any photograph, video, movie or television film for sale, hire or profit' in a marine park except with the consent of the Authority (clause 24/Schedule 2).

Victoria

On 18 June 2002 Victoria enacted the *National Parks (Marine National Parks and Marine Sanctuaries) Act* 2002 (Vic) to amend the *National Parks Act* 1975. The legislation established thirteen marine national parks and eleven marine sanctuaries on 16 November 2002, covering 5.3% of Victoria's marine waters. A number of offences are created in the Act such as taking or attempting to take 'fish or fishing bait for purposes other than for sale, unless that person does so under and in accordance with a permit' (penalty $6,600 and/or 6 months' imprisonment: s.16). It is asserted that native title rights are not affected by the legislation (s.19). Prohibitions on further activities such as jet skiing and anchoring of boats may be declared following the development of individual management plans. The Victorian Government has stated that it will provide an annual compliance and enforcement budget of $3.4 million (Department of Natural Resources and Environment 2002).

The legislation provides for compensation for 'eligible specified access-licence holders' determined by a Compensation Assessment Panel and reviewable by a Compensation Appeals Tribunal. The compensation package remains an issue of concern for many commercial fishers, particularly in the rock lobster and abalone fisheries, and it remains to be seen whether there will be legal action in this area. The issue of appropriate compensation for previous commercial users prohibited from undertaking their pre-existing activities within MPAs is perhaps the most politically charged issue facing MPA creation in Australia. However, the debate about government 'appropriation' of public marine space is also experienced elsewhere. Fishers in the USA have also claimed that the creation of MPAs amounts to 'taking' of their traditional fishing grounds and should be subject to compensation (National Academy of Sciences 2001).

ENFORCEMENT OF OFFENCES

Prosecution experience in Commonwealth MPAs

The EPBC Act created a number of severe civil and criminal offences that did not exist under previous legislation. Penalties for some offences include lengthy custodial sentences and, as mentioned above, fines for individuals up to $550,000. The Act came into force on 16 July 2000 and at the time of writing (September 2002) there have been no prosecutions for any of the offences created under the Act. Hence, there is as yet no opportunity to analyse prosecution proceedings. However, it is clear that the severe nature of the penalties would strongly deter individuals who might, for example, be inclined to fish regardless of whether such fishing is likely to have a significant impact on the environment (penalty: imprisonment for up to seven years and/or a fine of up to $46,200: s.24A(6)(7)). Even so, it is likely that only a flagrant breach of the Act would incur the maximum penalty. As with all offences, discretion on severe penalties depends on the nature of the offence and a possible due-diligence defence where, for example, appropriate environmental practices and management systems of the operator of commercial activities are in effect. Although it is only a matter of time before there is an attempt to prosecute an alleged offender under the EPBC Act, it is likely that this will occur only in circumstances where there is clear and convincing evidence that the offence has been committed. The award of a substantial penalty for the first successful prosecution under the Act would send a powerful message to would-be offenders in federal waters.

Prosecution experience in GBRMP

Around 70 convictions each year are recorded for offences in the Great Barrier Reef Marine Park. Illegal activity includes prawn trawling, for example when trawls commence lawfully in areas adjacent to the park and then overrun into the park (Gribble and Robertson 1998). Other offences include commercial fishing and recreational take in Dugong Protected Areas. Although penalties for individuals (since July 2001) range up to $220,000, most offenders receive penalties in the order of $1,000 (GBRMPA 2002b). However, on 12 August 2002 two commercial fishers were successfully prosecuted in Rockhampton Magistrates Court for intentionally and negligently fishing in a green zone. The maximum penalty available was $220,000 but the penalty issued was $27,500 plus costs and $6000 plus costs respectively (GBRMPA 2002d). There is also litigation concerning the owners and operators of the 225 m bulk carrier *Doric Chariot*, which ran aground and damaged a large area of reef in July 2002; prosecutors are seeking the maximum penalty available under the GBRMP Act, i.e. $1.1m.

Prosecution experience in Tasmanian MPAs

No prosecutions have been recorded for offences within Tasmania's MPAs even though the four MPAs have been in operation for twelve years. This is because Tasmania's MPAs are very small and are easy to avoid by recreational fishers, and they have limited impact on commercial fishers and other coastal zone users.

Prosecution experience in New South Wales MPAs

There have been no prosecutions for specific offences within NSW MPAs with the exception of a caution notice issued on 1 January 2002 under clause 7A of the Marine Park Regulations 1999 to a person in a sanctuary zone who was harming or attempting to harm an animal (Muldoon 2002). However, although the Marine Park Regulations 1999 are in force, they operate only in sanctuary zones for which management plans have been finalised. For example, the Jervis Bay Marine Park Regulations will enter into force on 1 October 2002. The Draft Zoning Plans for Lord Howe Island Marine Park are in the public-comment phase. The Solitary Islands Marine Park was declared in 2000. A new zoning plan, the Marine Parks Amendment (Solitary Islands) Regulation 2002, entered into force on 1 August 2002 and defines new offences of cleaning any fish or fishing gear within a sanctuary zone and carrying out dredging (schedule 1, clause 4 and 8A).

Analysis

The lack of a prosecution record for offences within MPAs in Australia (with the exception of the Great Barrier Reef Marine Park) is due in part to the difficulty of securing convictions, due to weaknesses in the evidence such as the short duration of the offences and the difficulty of identifying the boundary zones where most illegal activity takes place. Conviction of a tourist for unlawful fishing from a tourist vessel may require that the tourist has been informed by the tour operator of the regulations pertaining to that area. As stated above, DPPs are reluctant to prosecute alleged offenders unless there is a reasonable prospect of securing a conviction. Likewise, where MPA offences provide for relatively modest penalties, there may be greater inclination on the part of inspectors to prosecute technical breaches. On this point it is likely that there will be more prosecution actions commenced for offences under NSW MPA regulations where on-the-spot penalties are in the order of $300 to $500 than under the Commonwealth EPBC Act where penalties range to $550,000. Hence, there is merit in prescribing offences in the NSW manner, where lower penalties are listed in schedules that can be revised more easily than penalties embedded in provisions of Acts. Penalties may be increased quickly when the need arises, such as possibly providing for licence suspension and the confiscation of fishing gear for commercial fishers who commit offences. Areas of MPA management also requiring attention include the adequacy of measures to ensure that inappropriate activities, such as intensified fishing effort, do not take place in areas adjacent to MPAs. One consequence of MPAs is that fishing effort is displaced and fishers tend to 'fish the line' adjacent to MPAs.

The lack of prosecutions for MPAs also owes much to the use of education programs (including liaising with industry and other operational agencies) to promote compliance with MPA management plans (see Mascia 1999). Enforcement in MPAs is generally undertaken on a first level by education, which is seen as the most effective way of encouraging compliance. For example, the Great Barrier Reef Marine Park Authority states that enforcement action and prosecution 'are not necessarily the tools of first opportunity, nor are they always the tools of last resort' (GBRMPA 2002a). As a result, inspectors are encouraged to use their discretion in each case when determining the appropriate course of action. Increased public awareness about the purpose and benefits of MPAs helps to ensure greater community support for MPAs and willingness to comply with management plans. The need for community support for MPAs is apparent when one considers that it is a fairly radical – and recent – notion to prohibit a large range of traditional activities in marine areas, which are often seen as common property allowing free access. Education is also important considering the different regulations declared for each MPA and the difficulty for marine users to ascertain such information.

CONCLUSION

The Australian legislative experience with MPAs differs considerably from jurisdiction to jurisdiction, notwithstanding recent national attempts to clarify the selection and management processes for MPAs. Nevertheless, each legislative arrangement has the following characteristic: individual sites for MPAs must be selected and proclaimed under subordinate legislative instruments rather than entrenched in site-specific legislation. A consequence of MPA-specific management arrangements is that uniform enforcement policies cannot be created because different MPAs allow different human activities. This is particularly apparent when small MPAs are compared with large MPAs located in or near traditional commercial fishing grounds. Coastal zones with multiple uses tend to produce more complex management arrangements specifying numerous permitted uses. Strict no-take zones are likely to be easier to enforce than MPAs that permit a range of regulated activities, because incidents such as incidental by-catch simply cannot occur.

The prosecution experience for offences within MPAs in Australia is almost non-existent. The number of prosecutions in the Great Barrier Reef Marine Park can be explained by its long history and its vast size. Attention is now likely to focus on the effectiveness of the many newly created MPAs throughout Australia, including the adequacy of protection measures for areas adjacent to MPAs to ensure that prohibited activities do not take place within them, the willingness of inspectors to prosecute offenders, and the level of penalty the courts will order (especially for offences under the EPBC Act). It is likely that more offences will lead to the imposition of financial penalties by inspectors or will be prosecuted in the courts (and the protection of ecological values within MPAs ensured) if the penalties are relatively modest and reflect the severity of the offence. For fishing offences it is essential that the maximum penalty awardable exceed the commercial value of the catch. In particular, penalties that appropriately reflect the greater level of responsibility expected of commercial fishers would be likely to receive more public support than onerous penalties imposed on recreational fishers, such as may occur under the EPBC Act. Such an approach would also provide a rational base for enforcement and would complement existing education campaigns.

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HOW GOOD ARE THE AQUATIC PROTECTED AREAS – MEASURING THEIR PERFORMANCE

Theme 4

KEYNOTE PRESENTATION

MEASURING EFFECTIVENESS IN MARINE PROTECTED AREAS – PRINCIPLES AND PRACTICE

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Abstract

The protection of aquatic areas is a comparatively recent concept compared with the protection of terrestrial areas. The momentum for the protection of aquatic areas is increasing and all Australian States and Territories and most coastal countries worldwide now have some form of marine protected area (MPA) system with a wide variety of names, aims, objectives and intended benefits. Along with calls for more MPAs, there are growing expectations of more systematic assessment of the effectiveness of such areas. Increasingly, it is being recognised that effective resource management requires monitoring and evaluation to enable an adaptive approach to decision making.

There are compelling reasons why managers should measure the performance of protected areas, and a variety of managers are responding by seeking to objectively demonstrate management effectiveness. Although there are a number of key principles for such evaluations that can be transferred to aquatic systems from approaches developed for terrestrial protected areas, practical experience in measuring effectiveness in MPAs is, as yet, limited. This paper outlines some of the approaches, experiences, issues, challenges and benefits of evaluating management effectiveness in MPAs, and suggests a range of practical considerations for those endeavouring to measure effectiveness of MPAs.

The paper concludes that management practices for MPAs generally have a long way to go before evaluation of management effectiveness becomes a well integrated component of management systems. In many cases, the establishment of appropriate programs for evaluating management effectiveness requires major institutional re-orientation at the policy level. The challenge is for MPA managers, decision makers, funders and evaluators alike to bring about the changes required to see the establishment of evaluative management systems for MPAs as the norm rather than the exception.

***Keywords**:* marine protected areas, MPA, evaluation, measuring effectiveness, objectives

INTRODUCTION

The protection of aquatic areas, and in particular marine protected areas (MPAs), is a comparatively recent concept compared with the protection of terrestrial areas. Although the oceans constitute more than 70% of the earth's surface, MPAs cover less than 1% of the earth's surface, whereas terrestrial protected areas cover some 9%. The momentum for the protection of aquatic areas is increasing, and all Australian States and Territories and most coastal countries worldwide now have some form of MPAs or MPA system with a wide variety of names, aims, objectives and intended benefits.

Along with increasing calls for more MPAs, there are growing expectations for more effective management. Management in the MPA context usually includes attempts to "deal with issues of almost wholly human origin" (Walton and Bridgewater 1996) and trying to ensure that human activities do not overwhelm the resilience

*The views expressed in this manuscript are those of the authors and do not necessarily reflect the official views or policies of their affiliated institutions.

of natural systems. Effective resource management cannot occur without monitoring, evaluation and adaptive management. At the World Congress on Aquatic Protected Areas, held in Cairns in August 2002, the need to 'effectively measure performance' was considered to be of such importance that the organisers devoted one of five congress themes to it.

Worldwide there are increasing requirements for the evaluation of all management programs, and MPAs are no exception. Such evaluations need to demonstrate the effectiveness of management through evidence of results, rather than on the basis of educated guesses, 'gut feelings', or assurances like '*trust us we're the experts*' (Jones 2000). In recent years, governments have placed growing emphasis on outcome-based (rather than activity-based) performance reporting, which includes measures of performance in achieving objectives or targets. However, these calls for accountability and evaluation need to recognise:

- the wide variety of MPAs set up to achieve differing purposes and objectives, and
- the issue that "one size certainly does <u>not</u> fit all" (i.e. the approaches of managing and evaluating a multi-use MPA at the ecosystem level clearly differ markedly from those needed for a small single-purpose MPA(Agardy *et al.* in press) – and even within a multi-use park there may need to be different strategies.

Evaluation is often viewed as an 'optional extra'; good in theory but difficult in practice. Monitoring and evaluation programs, although supported in principle, often get displaced by more 'urgent' (though often less important) day-to-day management activities. However, without evaluation against objectives, managers are 'flying blind' and lacking the necessary evidenced-based feedback to learn from, and improve upon, past management approaches (Jones 2000).

Monitoring of MPAs is not new. Most monitoring programs, however, have been directed towards biological, biophysical or social aspects, and have generally been undertaken as 'stand-alone' monitoring or research tasks. Some of these programs assess the effectiveness of specific management actions, but few provide an integrated assessment of the overall effectiveness of the MPA or specifically monitor the key values for which the area was declared.

A range of groups/individuals around the world is now investigating more integrated ways to evaluate MPAs (e.g. Hockings *et al.* 2000; Mangubhai 2001; WCPA/WWF 2002). This work has developed largely as theoretical frameworks and is only now being applied in 'real-park' situations. Few substantial attempts have succeeded in evaluating the effectiveness of MPAs. Progress in implementing evaluation systems for MPAs is to some extent hampered by the inherent challenges presented by marine systems compared with terrestrial systems; these are discussed below.

This paper examines some of the frameworks for evaluating effectiveness that have been developed in recent years – primarily for terrestrial protected areas, but in recent years increasingly in MPAs. It also discusses various approaches and lessons learnt, and presents a range of practical considerations for those attempting to evaluate MPAs; it examines, in turn, the key elements of objectives, indicators, monitoring, reporting and adaptive management. The differing perspectives and/or responsibilities of managers, researchers, politicians and stakeholders with respect to evaluating the effectiveness of MPAs are also discussed. The paper concludes by examining the adequacy of current practices in evaluating effectiveness of MPAs in the light of the principles and guidelines discussed in the paper.

Many of the terms as used throughout this paper are defined in Appendix 1.

REASONS FOR EVALUATING MANAGEMENT EFFECTIVENESS

The evaluation of management performance and effectiveness in MPAs may be undertaken for a variety of purposes including the following (adapted from Hockings *et al.* 2000; Jones 2000; Mangubhai 2001):

Adaptive management

- Demonstrate / determine the extent to which the objectives of management have been achieved and that measures have been implemented/complied with;
- Enable more systematic and transparent linkage between management objectives and management actions, and identify gaps that can be consequently rectified;
- Provide evidence-based feedback about what's working and what's not, enabling review of management direction, priorities, resources, etc. for decision makers;
- Learn more about how the MPA and its management actually 'works' – including the ecological nature of the MPA, its dynamics and their interaction with management efforts;

Improving planning

- Review and prioritise MPA policies and programs;
- Provide for more informed decision-making and improvements in planning and field management for decision makers and interest groups;

Promoting accountability

- Promote openness and accountability in areas of management expenditure, resource allocation, maintenance of values and delivery of outcomes;
- Demonstrate that resources have been efficiently/effectively used to governments, funding bodies, interest groups and the public;

Encouraging appropriate resource allocation

- Reveal gaps in our knowledge and hence justify the need for additional or different resource allocations in a systematic way.

Although the above reasons argue strongly for measuring management performance, in practice this often entails major institutional re-orientation, and poses new challenges for managers/decision makers and 'evaluators' alike.

FRAMEWORKS FOR ASSESSING PROTECTED AREAS

The WCPA Management Effectiveness Framework developed by the IUCN Management Effectiveness Task Force (Hockings *et al.* 2000) provides a general framework for the design of a system to evaluate management effectiveness in protected areas. The framework represents the main elements of the 'normal' management cycle with various linked, iterative phases. Each of the six main management elements is clarified by a simple key question (Table 1).

Hockings *et al.* (2000), Jones (2000) and Mangubhai (2001) all recognise that the first, and most fundamental, requirement for measuring performance in any type of protected area (terrestrial or marine) is to set clear objectives. Effectiveness is then measured through the processes of monitoring and evaluation against those objective(s). Jones (2000) sets out the seven key steps in the evaluative process developed for the Tasmanian Wilderness World Heritage Area (Fig. 1).

Such evaluation needs to be an ongoing process and sufficiently adaptable to incorporate new data as it becomes available (i.e. management cannot be static). It is also important in Step 3 that a range of indicators be chosen to represent each of the key desired outcomes.

Table 1. WCPA Management Effectiveness Framework for assessing management effectiveness of protected areas (Hockings *et al.* 2000).

Elements of evaluation	**Design issues**		**Appropriateness of management systems and processes**		**Delivery of protected area objectives**	
	Context	**Planning**	**Inputs**	**Processes**	**Outputs**	**Outcomes**
Key Question	*Where are we now?*	*Where do we want to be?*	*What do we need?*	*How do we go about it?*	*What were the results?*	*What did we achieve?*
Criteria used to assess management effectiveness	Significance Threats Vulnerability National context	Protected area legislation & policy Protected area system design Reserve design Management planning	Resourcing of agency Resourcing of site Effectiveness of agency in implementing program Contributions from partners	Suitability of management processes	Results of management actions Services and products	Impacts: effects of management in relation to achievement of objectives, maintenance of values & abatement of threats
Focus of evaluation	Status	Appropriateness	Economy	Efficiency Appropriateness	Effectiveness	Effectiveness Appropriateness

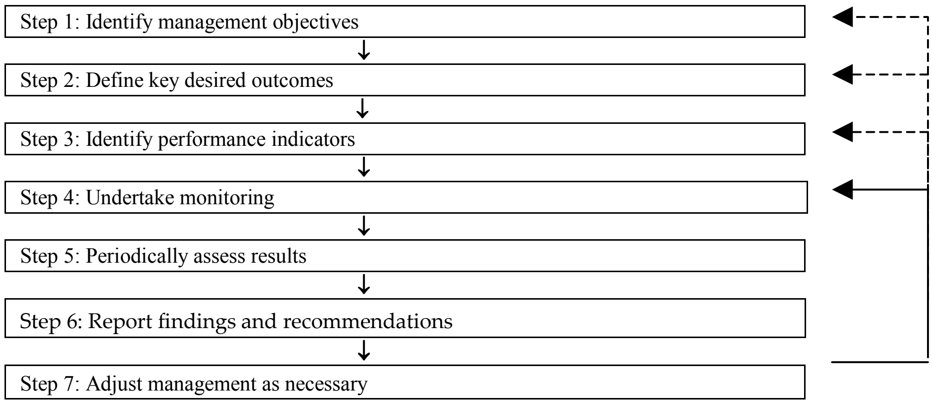

Fig. 1. Seven key steps for evaluating effectiveness of management (after Jones 2000).

SPECIAL CHALLENGES IN ASSESSING EFFECTIVENESS IN MARINE SYSTEMS

Major differences exist between terrestrial and marine systems (Slocombe 1992), and some of these pose inherent challenges for assessing effectiveness in marine rather than terrestrial systems (Day 2002). These differences include the following:

- the nature of marine ecosystems makes monitoring natural resources more difficult (also, the volume of the sea, and hence its habitable area, is many times greater than the land);
- there is a high degree of 'interconnectedness' in the marine environment in all dimensions;
- a far greater proportion of the marine realm does not receive light (so photosynthesis cannot occur);
- the pelagic realm has no counterpart in terrestrial ecosystems, insofar as there are no terrestrial species (let alone whole communities) that are completely independent of the ground or ground-based resources (Day and Roff 2000);
- logistical difficulties of sampling marine systems make it much more difficult and expensive than sampling terrestrial environments – much marine monitoring and management is 'transient', after which researchers/managers must return to land;
- many marine species are widely dispersed and individuals can be far ranging – even among those that can be considered static as mature forms (e.g. many molluscs and seaweeds), many species have highly mobile larval or dispersive reproductive phases (Day and Roff 2000);
- marine systems are dynamic, with natural changes that differ in scale from those in terrestrial systems (e.g. marine communities respond relatively quickly to changes but within a slow-reacting and insulating ocean, whereas terrestrial communities generally respond more slowly to changes but are buffeted by rapidly changing climatic factors); and
- knowledge of marine systems is relatively lacking. As David Suzuki said (2002), "*…to date all we have actually identified are … about 10–20% of all living things! How can we presume to manage natural resources when we have such a poor inventory of the constituents and a virtually useless blueprint of how all the components interact?*"

Many of the principles for 'measuring effectiveness' in protected areas were initially developed for terrestrial areas (e.g. Hockings *et al.* 2000; Jones 2000). However, although there are similarities, "*marine ecosystems are not simply wet salty terrestrial ones*" (Rice 1985). Many principles of marine conservation are different from those derived from experiences on land or with terrestrial protected areas. Rice (1985) observed "*The most serious problems arose when I assumed some knowledge I had gained in other contexts would transfer readily to marine contexts. It is not the case so often that one is better off assuming it is never the case, and occasionally being pleasantly surprised*".

HOW MIGHT SUCH EVALUATION FRAMEWORKS BE APPLIED IN MPAS?

Irrespective of the purpose(s) of the MPA, the principal measure of management effectiveness is the extent to which the management objectives are achieved. Regardless of the objectives for a particular MPA, stating the objective(s) in an explicit and unambiguous way is essential to evaluate effectiveness; this applies irrespective of whether it concerns a MPA with a narrow or single objective (e.g. single-species management) or a multiple-use MPA with a broad range of environmental, social and economic objectives.

Hockings *et al.* (2000) consider that the evaluation of management effectiveness for protected areas should take into account the assessment and monitoring of three broad components (as shown at the top of Table 1); for MPAs this involves the following:

1. **Design issues of the MPA** (e.g. objectives, purposes of use and entry; hence, size, shape, buffers, linkages, location of boundaries).
2. **Appropriateness of management systems & processes** (e.g. planning approaches, management implementation, training, relationships with local communities and private sector).
3. **Delivery of MPA objectives** (does the MPA achieve its stated goals and objectives?).

IUCN's "*Interim Guidelines for the Assessment of Management Effectiveness of MPAs in the Western Indian Ocean*" (Mangubhai 2001) builds upon the work done by Hockings *et al.* (2000) and is particularly relevant to MPAs. However, it is still largely theoretical and its application in the field has yet to be demonstrated.

In well established MPAs, outcomes are the most important single measure of effectiveness – has the MPA really achieved its intended objectives? Issues of context, planning, inputs and processes (Table 1) are also important aspects of measuring effectiveness and can contribute significantly to an outcomes-based evaluation as well as adaptive management; however, these other elements deal more with the 'efficiency' aspects than with 'effectiveness'.

For many 'paper parks' around the world or recently established MPAs, evaluation at the 'context end' of the spectrum or planning proposals is an important first step that provides understanding about critical aspects of the management system. However, such approaches must also be followed by further assessments of the elements related to the delivery of the MPA objectives (i.e. the outputs and outcomes). A truly comprehensive system for assessing performance of a MPA would include components of all six elements as defined by Hockings *et al.* (i.e. they are all complementary).

Ideally, the use of a range of approaches may be applied for evaluating management performance, i.e. measuring from a variety of information 'angles' such as performance indicators, stakeholder assessments and critical comment on management performance (Jones 2000), compliance, education and environmental condition. Collectively, this provides, as far as practicable, a balanced picture of management performance.

ARE THERE OTHER EVALUATION EXAMPLES THAT MIGHT BE USEFUL FOR MPAS?

Some experience has been gained from attempts to measure effectiveness in other marine situations. For example, fisheries managers have long attempted to undertake periodic stock assessments. Most attempts, however, have examined only single-stock fisheries as outlined in the example below:

> '*Effective management of a fishery requires periodic assessments of the status of the resource on which the fishery operates. Such assessments rely upon a process of stock or resource monitoring, which estimates the values(s) [sic] of one or more 'performance indicators' – often indices of stock abundance. Stock assessment is the examination and interpretation of a time series of performance indicator values. Translating the trends revealed by stock assessment into a specific management action can be achieved through the application of decision rules. These rules compare the performance indicators with pre-determined reference points, and if certain conditions are met, will automatically trigger certain management actions*'. (Queensland Government 2001)

Such single-species approaches are rarely appropriate in the evaluation of MPAs since most MPAs are managed for multiple objectives, often including biodiversity. The single-species approach does not, for example, address matters of non-target species or the wider ecosystem processes and functions. Furthermore, biodiversity objectives are often less specifically defined than fisheries management objectives and therefore present a more challenging arena for evaluation (Syms and Carr 2001).

In addition, the focus of management strategies in many MPAs is undergoing relatively rapid change from 'single species' to 'habitats', and in some instances to 'ecosystems' and to a diversity of permitted uses consistent with a variety of overall objectives.

A draft Guidebook for "The evaluation of Management Effectiveness of MPAs" is in preparation by a WCPA/WWF working group based on the WCPA Management Effectiveness Framework (Pomeroy *et al.* in prep.). Some innovative work on indicators is being finalised, with the working group examining biophysical, socio-economic and governance indicators. For each category, the draft report suggests a number of specific indicators correlated with a variety of management objectives and MPA goals – however the applicability of these indicators to a wide variety of MPAs is yet to be determined.

Table 2. Examples of specific evaluation assessments undertaken in the Great Barrier Reef

Type of evaluation	**Comments**	**Reference**
State–Pressure–Response model	Summarised in the *State of the Reef Report* 1998	Wachenfeld *et al.* 1998
Day-to-day management reports	Reporting quarterly & annually against targets set for such aspects as vessel patrols	DDM 2002
Reactive Monitoring Report for Great Barrier Reef World Heritage Area	Report to World Heritage Committee assessed against five priority action areas; updated annually 2000–2002	GBRMPA 1999
Effects of overflights by aircraft on nesting seabirds	A study to investigate the impacts of aircraft on seabird breeding	Hicks *et al.* 1987
Effects of sea dumping on nearby fringing reefs & seagrasses	A reactive monitoring program with decision thresholds developed to manage effects of port developments (dredging and dumping) on nearby corals & seagrasses	Benson *et al.* 1994
Environmental effects of prawn trawling in the GBR	A five-year study into the effects of trawling on seabed communities in the Far Northern Section of the GBR	Poiner *et al.* 1998
Long-term monitoring of key organisms across the Great Barrier Reef	Annual monitoring of status and natural variability of populations of corals, algae and reef fishes from 48 reefs and crown of thorns starfish from 100 reefs to assist with management decisions	Sweatman *et al.* 2000
Effects of line fishing	Monitoring recovery of exploited stocks following baseline surveys & manipulations of fishing closure strategies implemented as part of the CRC Reef Effects of Line Fishing Project	Mapstone *et al.* 2002
Audit of performance of East Coast Trawl Plan	Audit of the East Coast Trawl Management Plan to examine how well the trawl fishery is managed against the ESD objectives of Queensland fisheries legislation.	Huber 2003
Assessment of a new network of no-take areas against biophysical principles	Sets measurable objectives for 11 biophysical operating principles against which the proposed new 'no-take' network can be assessed	Day *et al.* 2000

Table 3. Draft Key Performance Indicators (KPIs) under development for the Great Barrier Reef Marine Park

Authority Goal	*To provide for the protection, wise use, understanding and enjoyment of the Great Barrier Reef in perpetuity through the care and development of the Great Barrier Reef Marine Park*	
Component of Goal	**Desired Outcome**	**Draft Key Performance Indicators** *(still being developed/refined)*
Protection	Improved water quality	**KPI 1** The trend in 'end of river' pollution loads for key Great Barrier Reef catchments
	Conservation of the biodiversity of the Great Barrier Reef	**KPI 2** The relative numbers of reefs that are 'healthy' rather than 'not healthy' as assessed by the Australian Institute of Marine Science Long-term Monitoring Program (Sweatman *et al.* 2000)
Wise use	Sustainable fisheries	**KPI 3** The proportion of fisheries (total fisheries *v.* well managed fisheries) with management plans and arrangements that comply with Federal guidelines for ecologically sustainable fisheries
	Effective park management	**KPI 4** The number of bioregions with adequate 'no take' zones is increasing
Understanding and enjoyment	Accurate and adequate information available for management	**KPI 5** The number of technical and scientific publications published about the GBR by GBRMPA and the Reef CRC is static or increasing.
	Improved community understanding of the Great Barrier Reef Marine Park	**KPI 6** Public understanding of the main threats to and the values of the GBR is increasing
	High-quality tourism and recreation opportunities	**KPI 7** Stable or increasing numbers of tourists to the GBR Marine Park are aware of regulatory requirements and best practice that relate to their activities

Experience in the Great Barrier Reef Marine Park

The Great Barrier Reef Marine Park (GBRMP) is certainly not a typical MPA in terms of its size or its complexity. After its declaration in 1975 as the world's largest MPA, various assessments have been undertaken to evaluate specific aspects of management (Table 2). Tables 2 and 3 outline the approaches and experience gained, which may have some relevance to other MPAs.

The examples shown in Table 2 are very much task-specific, however, and collectively do not constitute a systematic evaluation of management effectiveness across the entire Marine Park. In an attempt to move toward a more holistic MPA-wide evaluation, the Great Barrier Reef Marine Park Authority (GBRMPA) is also investigating a small number of Key Performance Indicators (KPIs) developed for the main objectives derived from the Authority's Goal (Table 3). These KPIs are not to replace any of the more detailed assessments, but rather will provide a 'broad-brush' evaluation that can be periodically assessed and reported at a MPA-wide scale.

PRACTICAL CONSIDERATIONS WHEN EVALUATING MPAS

Some of the broader issues and lessons learnt from worldwide experience of protected areas management that may assist in evaluating MPAs are as follows.

Objectives/outcomes

a. **Well-defined objectives provide a clear basis for evaluation**.

   Often, MPA objectives are too generalised or unclear to directly serve as a basis for evaluating effectiveness (for example "*to protect biodiversity*" is too broad to be directly measured; furthermore, this is virtually impossible to measure in most MPAs because much of the marine biodiversity still remains to be described). Mangubhai (2001) suggests that such objectives need to be clarified or restated in more practical terms, through the use of SMART objectives: Specific, Measurable, Achievable, Realistic, Time-limited.

   Jones (2000) stresses the need for objectives to be articulated into clear statements of 'Key Desired Outcomes' that define the tangible results that would be expected if the objectives were fully realised. Such statements then provide a practical basis for evaluating management effectiveness. In addition, Jones suggests that, as well as considering what outcomes ARE desired, it is often helpful to consider what outcomes would NOT be expected if the objective/s were fully realised. This step helps to clarify the polarity of outcomes that might potentially be expected, and assists in identifying appropriate performance indicators to be monitored.

b. **Effectiveness needs to be evaluated with respect to stated objective(s) and targets**.

   The mandate of the managing agency has a significant influence on the goal or objectives of a MPA. For example, a MPA with a goal or objective for fisheries management is quite different from a MPA designed primarily to protect biodiversity or to function as a reference area. Note that the achievement of many MPA objectives is influenced by factors outside the MPA jurisdiction or not under the control of managers (i.e. the wider context of migratory species). This can lead to difficulties both in monitoring and effective management of these factors outside the relevant MPA.

Indicators

a. **It is rarely practical to monitor or measure performance indicators for every aspect of every objective**

   This applies particularly for complex MPAs with a multitude of objectives. Consider instead measuring a 'key' set of indicators that reflect significant or strategic aspects of the overall MPA and its broad objectives.

b. **Indicators need to be relatively simple and cost-effective**

   This applies in terms of data collection, analyses and interpretation. Wherever possible, use existing programs rather than 're-inventing the wheel'.

c. **Use input from local managers**

   The identification and selection of meaningful and practical indicators should rely heavily on input from those with local management knowledge and/or specialised expertise.

d. **Recognise 'shifting baselines'**

   When attempting to monitor change in environmental systems, be aware of the issue of 'shifting baselines' and avoid the potential for major problems that can arise if inappropriate reference points are assumed or improper targets are selected. As Pauly (2001) explains "*Each generation accepts the species composition and stock sizes that they first observe as a natural baseline from which to* *evaluate changes. This ... ignores the fact that this baseline may already represent a disturbed state. The resource then continues to decline, but the next generation resets their baseline to this newly depressed state. The result is a gradual accommodation of the creeping disappearance of resource species, and inappropriate reference points."*

e. Have a clear focus on the 'right' question(s)

It is much better to have a clear focus on the right question, and apply a low-power assessment program, than to apply a high-power assessment program to the wrong questions. Focusing on monitoring 'easy' or established indicators may result in information about the wrong questions. Many monitoring programs 'do the thing right' (i.e. precise local measurements) rather than 'doing the right thing' (Walters 1997). The best starting point for developing a sound set of indicators is to ensure that clear objectives/outcomes are defined before indicators are developed.

f. Develop socio-economic indicators

For most MPAs, there is a need to develop socio-economic indicators as well as the more usual ecological and management indicators.

g. Prioritise the needs for monitoring

Remember that the costs of conducting performance evaluation need to compete realistically alongside other demands on the budget. The level of resources applied to evaluation may be influenced by many factors. Hockings *et al.* (2000) provide guidelines on the level of effort that should be expended on evaluation based on the significance, extent of threat and level of use of the site and the capacity of the management agency.

h. Recognise the many sources of uncertainty inherent in natural systems

The challenge is to develop performance indicators and protocols that are robust to the many sources of uncertainty inherent in natural systems (Syms and Carr 2001).

Monitoring

a. Start with a modest monitoring program

It is better to start with a relatively modest monitoring program for a few key performance indicators and expand programs as guided by experience. Jones (2000) considers that priority should be given to monitoring programs that provide information.

1. about the extent to which key objectives are being achieved (or are failing to be achieved);
2. about the condition of the most significant conservation values (especially those that are perceived to be at risk);
3. that can help resolve important, complex or controversial management issues.

b. Consider what are the most appropriate monitoring methods

In some instances a combination of monitoring methods may provide better or more reliable assessments than use of just a single method.

c. Determine who is best able/suited to undertake the monitoring

Consider and clearly establish who is best able/suited to undertake the monitoring (e.g. should the program be conducted internally or externally? – there are pros & cons with each). Where possible, use MPA managers who are regularly on the water to assist with monitoring.

d. Consider opportunities for participatory monitoring and evaluation programs

Wherever possible, encourage stakeholder participation or local input in the overall evaluation process. There is also a need to develop cooperative working arrangements for monitoring with a variety of other users who may already be out in the MPA in reasonable numbers – whether they be fishers, divers, tour operators or local volunteers. In all instances, careful training is required to ensure that monitoring data are accurate and meaningful.

e. Managers cannot afford to wait for perfect science before taking management action

So long as data are relevant and valid, there is obvious value in obtaining quick, easily accessible results rather than waiting several years for refined presentation of the findings in a scientific publication. For example, the long-term monitoring results (Sweatman *et al.* 2000) conducted by the Australian Institute of Marine Science are placed on the Internet in a readily usable format within weeks of the completion of a survey.

f. Monitor the 'performance' of management

The difference between the initial value and the 'target' of a performance indicator may be used to represent the 'performance' of management for the MPA and the effectiveness of management. Iterative approaches to management can then lead to continuous improvement in performance.

g. Consider innovative monitoring approaches that may be more affordable/acceptable

Development of affordable/acceptable monitoring programs for some MPA areas may involve innovation in scientific methods and approaches; for example, the Baited Remote Underwater Videos (BRUVs) to monitor fish species, abundance and size were developed by the Australian Institute of Marine Science when destructive sampling techniques were no longer acceptable in certain MPA zones (M. Cappo, *pers. comm.*).

h. Consider need for monitoring a wider context than within an individual MPA

There is a often a need to measure indicators both within the MPA and outside the MPA to determine relative changes (for example, to establish whether detected changes are due to management actions or other factors; or to determine whether the objectives of the MPA are being achieved in comparison with non-MPA areas).

Reporting

a. Reports of evaluations should be open, transparent and accessible to the community.

Reports on the effectiveness of management are usually of interest to a wide range of parties including the MPA managers, other MPAs, other agencies, governments, interest groups (funding bodies, NGOs, indigenous communities) and international community programs. Reports may take many different forms; written reports/papers are the most common, but increasingly there are moves toward the Internet and other mass media.

b. Think about the reporting requirements at the outset of project

It is important to think about the reporting requirements at the outset of the project, especially the target audience and the way the report style and level of detail are to be tailored to meet their needs. Verbal reporting may be the most appropriate means for communicating the findings and recommendations of evaluations to some stakeholder groups (e.g. Aboriginal, local community, field staff, etc.). It is also important to consider the appropriateness of timing for the release of an evaluation report, especially if using the mass media.

c. Reports should be produced regularly on a timeframe that integrates with the management planning cycle (e.g. 5 yearly).

This allows the findings and recommendations of the report to influence the review of ongoing management strategies (e.g. through adjustment of the management plan for the area).

d. Identify areas where management has been performing well, as well as identifying opportunities for improving effectiveness.

The inclusion of a concise summary of the key issues and opportunities for improving effectiveness identified by the evaluation can assist managers and other decision makers to improve ongoing management performance.

e. 'A picture can paint a thousand words'

The use of photographs, graphs and other visual methods to show trends in performance is often far more effective than reams of words.

f. Consider the opportunities for developing 'nested' reports

One requirement for performance reporting may provide input to, or become part of, a higher level or more complex reporting requirement, e.g. consider what aspects of statutory annual reports might be used for other reports, such as five-yearly "State of the Environment" reports or six-yearly "Periodic Reports" required by the World Heritage Committee. Similarly, consider the desirability of reporting on objectives to be undertaken at different jurisdictional levels.

Adaptive management

a. Take an adaptive management approach

An adaptive management approach is essential because MPAs are dynamic natural systems, and are commonly subject to changing patterns and levels of use, technological change, social change, and political change.

b. Measurement of management effectiveness usually cannot be 'tacked on' to the end of a management program

Measurement of management effectiveness needs to be an integral part of the management/planning process. Aim to get monitoring, evaluation and reporting integrated as part of the periodic management/planning cycle. Most, if not all, management approaches need to be periodically reviewed and adjusted, and a successful management regime cannot be inflexible to new information.

c. Use evaluations to feed into and influence ongoing management strategies

Management processes need to be in place to allow the findings and recommendations of evaluations to feed into and influence ongoing management strategies. For example, budget allocation and management planning processes need to formally address the findings and recommendations of any evaluation.

d. Develop strategic priorities for monitoring

The identification of critical gaps and/or uncertainties in information required for the effective management of MPAs should be one of the key inputs to developing strategic programs of directed research and monitoring (e.g. GBRMPA's Research Priorities, Green *et al.* 2001).

e. Evaluation systems and indicators are unlikely to be perfect when first developed

Rarely is the right information immediately available; hence, the process of evaluation – like management itself – needs to continuously adapt and improve.

RESPONSIBILITIES OF MANAGERS, SCIENTISTS AND DECISION MAKERS FOR MEASURING THE PERFORMANCE OF MPAS

Managers, scientists, stakeholders and decision makers often have differing needs and priorities when it comes to evaluating and reporting on the effectiveness of MPAs (Rogers 1998). Lawrence *et al.* (2002) list a number of philosophical and practical differences between research scientists and environmental managers, including time frames and primary goals, as well as their basis for decision-making, expectations and focus. Downes *et al.* (2001) refer to the interplay between science and management that "*has proved a fertile ground for mutual misunderstanding of each others' disciplines in terms of objectives, roles and outputs*".

There is therefore a need to collectively determine what is required of any evaluation and who is best able/suited to conduct the necessary monitoring programs and assessments, and who is responsible for reporting the findings and recommendations. There are challenges for all those involved.

- Challenges for MPA managers include:
  - to clearly define management objectives and desired outcomes;
  - to clearly articulate key management issues, especially those that are causing uncertainty or controversy in management actions;
  - to secure ongoing commitment to evaluating management effectiveness from senior executives and funding bodies; and
  - to involve program managers and other key staff (evaluation needs to be a team effort, both in principle and in practice).
- Challenges for scientists include:
  - to involve managers in monitoring and convince them of the relevance of their work;
  - to focus on problems of immediate usefulness to management rather than on issues of intellectual challenge or difficulty (Cullen 1990);
  - to provide information back to managers that is in a form that can readily be used or applied; and
  - to move away from destructive sampling practices wherever possible to new approaches e.g. Baited Remote Underwater Video systems, (M Cappo, *pers. comm.*).

All those involved also face the challenge of increasing public understanding of MPA issues, and the necessity to demonstrate to governments, funding bodies, interest groups and the wider community that public resources are being managed effectively and efficiently.

HOW WELL ARE MPA MANAGERS REALLY DOING IN EVALUATING EFFECTIVENESS?

Comparison of the present practices in MPAs with the abovementioned considerations for evaluating effectiveness suggests that most MPAs are a fair way from achieving the full benefits of evaluation. More often, the realities differ from the principles or the preferred results:

- There are many theoretical calls for comprehensive evaluation of protected areas
  …. the reality is few management agencies have implemented such systems.
- Most efforts to date have concentrated on the ecological aspects/condition in a few selected areas
  …. few are really comprehensive evaluations of management effectiveness, and
  …. very few have included social or economic aspects.
- Many evaluations have depended on staff from educational or research institutions

…. very few have been conducted by or involved management staff.

- Most management plans today refer to adaptive management and the need to monitor performance
  …. day-to-day management matters frequently displace longer-term strategic monitoring and evaluation programs (see Jones 2000). The main excuses for not evaluating effectiveness seem to be high cost, institutional barriers (Walters 1997) and lack of political support.

Although measurement of the effectiveness of MPAs is both reasonable and logical, its integration with management systems that are already in place provides significant challenges. However, if managers, decision makers and stakeholders are serious about demonstrating and improving management effectiveness for MPAs, then measuring management effectiveness needs to be recognised as an essential component of sound conservation management.

CONCLUSIONS

There is now widespread recognition that monitoring, evaluation, reporting and adaptive management are fundamental components of effective resource and conservation management. Present national and international directions in environmental management and planning also support the evaluation of effectiveness.

Establishment of robust systems for evaluating management effectiveness of MPAs poses significant challenges for managers, decision makers and evaluators alike, and requires major institutional re-orientation at the policy level. To achieve this:

- Management systems for MPAs need to be developed and/or adjusted so as to integrate the evaluation of management effectiveness. This includes clearly articulating management objectives, establishing appropriate monitoring programs for performance indicators, regularly reporting the findings and recommendations of evaluation, and adjusting ongoing management to progressively improve management effectiveness.
- The fundamental need for virtually all MPAs is to develop a set of clear objectives and realistic indicators against which effectiveness can be practically gauged. The lack of sufficient knowledge about MPAs, however, often prevents the setting of meaningful objectives in outcome-oriented (and hence measurable performance) language. The objective of 'protecting biodiversity' has problems as discussed above, but in reality this, together with some basic habitat information, is frequently the key aspect upon which an objective might be based for many MPAs being established in Australia. If the present state of knowledge does not allow objectives to be articulated into statements of desired outcomes, there is a need to establish interim surrogates (which initially may be relatively simplistic), together with a process for progressively improving the surrogates until the knowledge base becomes sufficient to enable meaningful statements of desired outcomes to be developed.
- Given limited resources, evaluations usually focus on providing information that is useful to management. Unfortunately, **potential** problems are often not accorded high priority for monitoring. Monitoring only the problems we already know about is criticised by many as 'throwing good money after bad' to prove yesterday's news, whereas what is needed are resources to detect and avert tomorrow's disasters. There is, therefore, a need to put in place a system of monitoring for the unexpected; evaluations should be focused **equally** on issues for management and on the main values for which an MPA was established (T Ward, *pers. comm.*). This then enables a 'safety net' to be put in place to ensure that monitoring does not miss entirely unexpected changes to the main MPA attributes (e.g. the approach to choosing marine indicators in Ward *et al*. 1998; Ward 2000).
- The findings and recommendations of evaluation must be regularly reported and presented in a manner that is understandable to stakeholders and usable by managers and other decision makers.
- Management and/or other decision-making processes for MPAs need to respond to the findings and recommendations of evaluation in order to progressively improve the effectiveness of management, e.g. through budget allocation processes.

A critical step, therefore, is not just to set appropriate objectives, but to set in place objectives that recognise the need for use of surrogates (initially highly simplistic) and secondly, a process for progressive improvement of the surrogates so that objectives can be appropriately refined as the knowledge base improves (T Ward *pers. comm.*).

The real test of success of any evaluation is the extent to which the findings and recommendations feed back into and bring about changes that improve ongoing management for a MPA.

We conclude that, despite the fact that what needs to be done is now well recognised, few MPAs in Australia, or around the world are adequately evaluating their effectiveness. The biggest challenge for MPA managers, decision makers, funders and other stakeholders is to bring about the changes required to see the establishment of sound evaluative management systems for MPAs as the norm rather than the exception.

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APPENDIX 1

Key terms as used in this paper are clarified below:

adaptive management – a structured process of continuously improving management performance through "learning by doing and measuring". However it should involve more than just monitoring and responding to unexpected impacts and should include the application of dynamic models that attempt to make predictions about the impacts of alternative policies (Walters 1997).

evaluation – the careful consideration of evidence that allows for informed judgement to be made of the performance of management against some predetermined criteria (usually a set of objectives, goals, targets or standards), normally based on the measurement of performance indicators.

indicators - a measure (quantitative or qualitative) that is indicative of the condition of some aspect of the system as a whole (ANZECC Task Force 1998).

management *(of MPAs)* – the sum of all decisions and actions that relate to the achievement of the purposes and objectives of the MPA. Management in the MPA context usually includes attempts to "deal with issues of almost wholly human origin" (Walton and Bridgewater 1996) and trying to ensure that human activities do not overwhelm the resilience of natural systems.

management effectiveness *(of MPAs)* – the extent to which a MPA has achieved its objectives. A comprehensive assessment of management effectiveness includes consideration of:

- the appropriateness of design of the MPA;
- the appropriateness and adequacy of management systems and processes; and
- the extent to which the MPA objectives have been delivered and values maintained (Hockings *et al.* 2000).

monitoring – the process of repeated observations for specified purposes, using comparable standardised data collection methods according to a prearranged schedule in space and time (Meijers 1986). As discussed by Hockings *et al.* (2000), monitoring can address far more than the state of the external physical and social environment and, in the context of this paper, can address the activities and processes of management.

INDICATORS TO ASSESS CORAL REEF CONDITION: INTEGRATING VIEWS OF SOCIETY

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Abstract

To achieve adaptive management, resource evaluation is required. Reporting the success of management strategies to the community maintains enthusiasm for protected areas and encourages adoption of sustainable activities. People need to be able to evaluate the costs of changing their activities or complying with management strategies in the context of the benefits of an improved state of the natural environment. Ideally, evaluations should provide information for both managers and the community. The identification of suitable indicators has hampered the evaluation process. I discuss the selection of indicators to access change in coral reef condition associated with anchoring. To ensure the indicators are useful for both managers and the community they are identified from two broad perspectives: the objective science and the subjective community approach. The benefits of integrating community views when selecting indicators are: 1) increasing involvement in resource management; 2) raising awareness of environmental change; and 3) identifying the community's perceptions of success.

Keywords: community participation, indicators, anchor damage, coral reefs

INTRODUCTION

Indicators that measure environmental condition are required to conduct evaluations of management strategies (Dudley *et al.* 1999; Hockings and Phillips 1999). Evaluating the state of the environment facilitates adaptive management and maintains enthusiasm for protected areas. To conduct evaluations, indicators that measure important attributes of the resource are needed. The choice of indicators is critical to how people construct and solve environmental problems (Machlis 1992). Indicators are needed to measure management objectives and encourage conservation (Hockings 2000). It is unlikely that one indicator could be useful for both purposes. For raising awareness of environmental problems, it may be more effective to use subjective rather than objective measures of the environment. In terrestrial environments the use of charismatic species, such as pandas and elephants, as indicators is an effective awareness-raising strategy (Machlis 1992). Similarly, there may be elements of coral reefs that are important to local communities, although not to scientists, that could be useful indicators.

Encouraging community participation in conservation, both within and outside protected areas, benefits natural environments and the community involved. Communities initiate and manage some marine protected areas (MPAs) (Katon *et al.* 1999; Chuenpagdee *et al.* 2002; Hodgson and Liebeler 2002). In the Philippines, rapid population growth increased destructive fishing practices, including the use of cyanide, blast fishing and small-mesh nets (Katon *et al.* 1999). The increased fishing effort devastated coral and fish populations. Shared community and government fisheries management schemes have since established MPAs. The local community conducts the day-to-day running of the protected areas causing a decline in illegal fishing practices. People reported benefits from the joint management arrangements, including increased knowledge, better information exchange, faster conflict resolution and more fisheries resources. The cover of coral and abundance of fish have increased within the MPAs (Katon *et al.* 1999). Similar increases in fishing pressure in San Felipe, Mexico, led to the establishment of an MPA by a fishing co-operative and groups of local fishermen, without the support of state or federal governments. Fishers' knowledge was used to ensure that important nursery grounds for lobster, grouper and octopus were included in the protected area (Chuenpagdee *et al.* 2002). Although levels of illegal fishing have declined, resource condition since closure has not been evaluated.

Monitoring environmental condition by local community groups is an effective way to involve people in conservation. Monitoring techniques are generally developed by scientists and modified to suit the skill and financial level of the community. Reef Check, for instance, mobilised 5000 volunteers to measure coral reefs around the world. Scientists trained the volunteers, and supervised monitoring and data collation. Volunteers were also taught about the ecology and value of coral reefs. Involvement in Reef Check has led to the initiation of new coral reef management activities and established a measurably successful marine park (Hodgson and Liebeler 2002). Using media coverage, Reef Check additionally raised awareness of coral reef degradation with people not directly involved with monitoring.

Often questions are raised about the rigor of data collected by community groups and whether the data can provide useful information for management decisions. However, groups such as Water Watch in Australia have shown that their techniques are consistent, and their data have been incorporated into government databases and management decisions (Carr 2002).

Monitoring by community volunteers extends the spatial and temporal replication of data beyond those collected by professionals alone. In addition, selection of indicators with greater local meaning than the standard scientific measurements could increase community awareness and motivate action. For instance, indigenous cultures use indicators within the environment to rate the stocks of hunted species or quality of pastures prior to exploiting the resource (Berkes and Folke 2000). Gasteyer and Flora (2000) found that community action was stimulated when the problem of water turbidity was expressed as the depth at which one could no longer see a pair of white tennis shoes. Expressing the problem in familiar terms led to greater efforts to reduce effluent and soil erosion. Use of community-based terms to describe coral reef condition could increase conservation efforts.

This paper explores the tension between objective and subjective knowledge systems with relation to descriptions of coral reefs. I describe how indicators that measure changes to coral reef condition associated with different levels of anchoring could be identified using people's perceptions and ecological measurements. The indicators developed by these techniques may extend people's involvement in conservation of coral reefs in three ways. First, the indicators identified by ecological techniques can be used to monitor coral reefs according to the classical community monitoring design. Second, showing people underwater scenes of coral reefs may increase awareness of environmental change. Finally, using perceptions of coral reefs may identify elements that people value. If people see changes to an element of high value, conservation efforts might be initiated or intensified.

COMMUNITY INDICATORS OF CORAL REEFS

Coral reefs are popular tourist destinations; therefore, research has been conducted on the links between coral reef condition and visitor satisfaction. Visitors rate experiencing nature or seeing natural beauty as the most important influence to their satisfaction (Shafer and Inglis 2000). People are therefore highly aware of their surroundings. Corals and fish have a positive influence on enjoyment of coral reefs (Shafer *et al.* 1993); in general, visitors rated highly the condition of corals and fish on trips to the Great Barrier Reef. However, condition of corals and fish was rated higher by snorkellers than by non-snorkellers. Return visitors rated coral condition lower than did first-time visitors (Shafer *et al* 1993). Therefore, experiences influenced the judgements of environmental condition. The condition of the coral reef visited by the people surveyed was not measured. However, it appears that the size, amount, colour and number of types of both coral and fish influenced the perceptions (Shafer *et al.* 1993).

Divers who return often to the same sites detect change to environmental condition. Long-term divers at Julian Rocks perceived a decline in marine environmental condition coinciding with increases in numbers of recreational divers (Davis *et al* 1995). Divers surveyed in Bonaire remarked that the under-water visibility had deteriorated over a five-year period (Dixon *et al.* 1993). Experienced divers at Bonaire noted a decline in coral cover, but not an increase in sand, suggesting that there were more dead corals than previously seen at the site. Ecological surveys identified a decline in coral cover and an increase in dead corals around the dive site, confirming the divers observations (Dixon *et al.* 1993). These surveys suggest that divers, particularly those with experience, are observing the changes in environmental conditions that are detected by scientists.

People with and without reef experience were asked to rate coral reef scenes with respect to ideal image and perceived health (Fenton *et al.* 1998). Both groups of people gave remarkably similar judgements. Typical images of coral reefs from the Great Barrier Reef were rated lower for health than the perceived ideal images. Low ratings were given to coral reef scenes showing damage from crown of thorns starfish (*Acanthaster planci*) and cyclones (Fenton *et al.* 1998), suggesting that people detect coral damage. The photographs used in the survey were not measured ecologically; therefore, it is not known whether particular types of coral, fish, or a change in coral cover or condition influenced perceptions.

People detect changes in the condition of coral reefs, but there appears to be some difference between the amount of experience a person has and their judgement. To explore which elements of the coral reef environment influence the judgements, my research conducts ecological and perceptual surveys together. Furthermore, participants in the perceptual survey are targeted to include people with a range of coral reef experience. The perceptual surveys use photographs taken from coral reefs associated with different levels of anchoring to identify useful community indicators. Photographic surveys provide a useful representation of the environment (Shuttleworth 1980). In comparison, written surveys may restrict focus and preempt answers, since the researcher may provide the environmental cues. Furthermore, management strategies and environmental changes are perceived more negatively when presented as written descriptions than as photographs (Tahvanainen *et al.* 2001).

Preferences for different types of environments are a combination of biophysical, psychological and phenomenological elements (Fenton and Reser 1988). Therefore, evaluations of the three elements are required for an understanding of perceptions. The initial focus of photographic surveys relates preferences and biophysical elements within the scene. The researcher quantifies the biophysical elements, including measurement of the area and perimeter of each biological element present, and estimations of the slope and relief. The scenes are presented to people to ascertain their preference. Preferences for terrestrial landscape scenes are related to the areas of vegetation and water (Bell *et al.* 1996), but it is not known what biophysical elements of underwater coral reef scenes are important to people.

The variation between preferences can not, however, be attributed solely to biophysical elements within the scene. Furthermore, the predictors do not always make intuitive or theoretical sense (Bell *et al.* 1996). Therefore, the second stage of the photographic survey relates preferences to psychological or cognitive processes rather than to biophysical elements. Kaplan and Kaplan (1989) suggested that preferences for a scene were related to predictors such as complexity, mystery, coherence and legibility. However, these predictors were not constant between scenes; for example, complexity could predict preference for one scene and mystery for another. Different types of predictors could be important in underwater scenes, for example, turbidity, colour and light.

Preference for a scene relates not only to the presence of certain biophysical elements, or psychological predictors, but to experiences and beliefs. Therefore, the last stage of the survey follows the phenomenological approach, which identifies preferences based on subjective descriptions related to experience. Preference for a scene varies according to familiarity, knowledge and experience (Purcell 1992). For example, people who had spent time in a wetland setting preferred that scenery to alpine scenery that is usually preferred (Műgica and Lucio 1996). To explore the relationship between experience and preferences for coral reefs, managers, scientists and people from the local community are surveyed. People are asked to describe differences between scenes and to judge the health of the coral reef in each scene. The coral reef the scenes presented to people are from the same location as the ecological survey.

ECOLOGICAL INDICATORS OF CORAL REEFS

Natural scientists measure many different components of coral reefs and there is conjecture about which element would best describe changes to coral reef condition associated with different levels of boating use. Measuring damage to corals may provide the most useful indicator. However, physical damage occurs as a result of both human and natural impacts, and identifying the cause of the damage is difficult. Dustan and Halas (1987) found significant amounts of fragmentation of *Acropora palmata* at heavily used areas of Carysfort Reef (Florida Keys). These fragmented areas also contained high numbers of broken propellers, lines, personal effects and other debris. Researchers used presence of "human debris" and lack of damage in adjacent low-use areas to suggest that recreational use caused the recorded damage. Jameson *et al.* (1999) did not identify the cause of damage, but compared the amount of broken corals and percent cover of rubble at high-use sites with rates of natural damage recorded in the literature. High numbers of overturned, gouged and fragmented colonies were found on reefs associated with high anchor use on the Great Barrier Reef (Malcolm 1998). Measuring one or all of these types of coral damage may provide a useful indicator of change in coral reef condition associated with anchoring.

Percent cover of benthic categories is widely used for monitoring reefs throughout the world and is particularly useful in observing gross changes to coral communities over large areas. Mortality of corals and increase in algal cover is a sign of coral reef degradation (Done 1992; Hughes 1994). However, there are some problems in interpreting this indicator for coral reef condition, because there is a need for earlier baseline data, which are often not available (Bak and Meesters 1998). Often, a change in coral cover is reflecting a change in one or possibly two major taxa, for example, the status of tabular *Acropora* drove many changes in coral cover on the Great Barrier Reef (Sweatman *et al.* 2000). How the growth and death of a fast-growing coral affects long-term coral reef health is debated (Sweatman 1999).

Number of species affects diversity and structural complexity of coral reefs. Coral reefs generally have high numbers of species and structural diversity, although corals can also form mono-specific stands. Disturbance can influence the relative occurrence of coral species on a reef. For example, high use by boats might deplete fragile species. Species that are associated with, or missing from, coral reefs may affect how people perceive them and make useful indicators.

The health of individual corals is important in determining the overall health of a coral reef. Coral diseases are present in low prevalence on the Great Barrier Reef (Dinsdale 2002), and are an important cause of mortality of coral reefs in the Caribbean (Aronson and Precht 2001). Coral bleaching, where individual colonies lose their symbiotic zooxanthellae, is a sign of stress and is highly visible on affected reefs. Another major cause of mortality of corals that affects the health of coral reefs on the Great Barrier Reef is outbreaks of *A. planci* starfish. Whether signs of coral stress are greater on reefs with higher levels of visitation requires investigation.

Large coral colonies are important in populations for their increased reproductive output and structural complexity. Large corals have high aesthetic value. To maintain coral communities and visitor satisfaction, these colonies need to be protected (Done 1995; De Vantier *et al.* 1998). Hawkins and Roberts (1993) found smaller colonies in trampled areas, attributable to higher rates of fragmentation and lower growth rates. Size structure of coral communities supplies information on the time between disturbances (Bak and Meesters 1998). Therefore, size structure could be a useful indicator of the condition of coral reefs influenced by different levels of boating activity.

My research is unique in identifying the most useful indicators to describe changes in coral reef condition associated with anchor damage from two perspectives: the objective science and subjective community approach. To identify the indicators, surveys are conducted at three sites with high levels of anchoring and three sites with low levels of anchoring (Dinsdale and Harriott 2003). At each site the following ecological variables are measured, the amount of damage, disease, coral cover, species diversity and size frequency of selected species. The sites are photographed and shown to people for their perceptions. Seventy-six participants with a range of coral reef experience provided their perceptions of the coral reef scenes depicted in the photographs. The views of people and the ecological measurements can be compared to identify the components of coral reefs that are important for people's perceptions. The variables identified from the ecological and perceptual surveys that differ with anchoring intensity are evaluated for robustness, cost and ease of interpretation. The variables that met most criteria will be selected as the most useful indicators of coral reef condition associated with different levels of anchoring.

APPLICATION OF THE INDICATORS

Since management strategies have multiple objectives, my research identifies indicators of coral reefs from different perspectives. Therefore, the condition of the coral reef under different management schemes could be described in terms with which either scientists or non-scientists are familiar. Managers could use the indicators to evaluate the effectiveness of their strategies and the local people could use the indicators to see the benefits to the environment of changing their activities. My research may identify an indicator of coral reef environments that is not usually measured by scientists, but is important to the people who use the reef. The use of community indicators to describe change may motivate people to conduct their activities more conservatively.

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MUD CRAB (*SCYLLA SERRATA:* PORTUNIDAE) POPULATIONS AS INDICATORS OF THE EFFECTIVENESS OF ESTUARINE MARINE PROTECTED AREAS

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Abstract

A primary objective of marine parks is to allow controlled access to users while conserving the environment. Zoning is seen as an effective way of managing populations vulnerable to over-fishing but indicator species are needed to show the effectiveness of these zones. As zoning of the Solitary Islands Marine Park (SIMP) on the mid-north coast of New South Wales, Australia,was implemented in the absence of adequate scientific data, we compared abundance, size classes and recruitment of mud crabs in adjacent fished and unfished zones in the SIMP to determine their effectiveness. The study was done in the Wooli Estuary where recreational fishing has been excluded from the Sanctuary Zone since 1991 but has occurred in the adjacent Recreation Zone. Mud crabs were sampled monthly in each zone from December 1998 to June 2002 using commercial wire traps. During the study, 1412 mud crabs were caught, tagged, measured, and sexed. Abundance and mean size of mud crabs was consistently higher in the Sanctuary Zone. Small sub-adult crabs dominated the population in the Recreation Zone. Recruitment of adult crabs to the Recreation Zone from the Sanctuary Zone, implied the Sanctuary Zone is an effective source. However, females still need to move through the Recreation Zone to reach the sea to spawn and recreational fishing may be a significant source of mortality. This study shows that targeted recreational species such as mud crabs respond to protection, and zoning in the Wooli Estuary appears to be an effective tool for sustainable fisheries management.

Keywords: mud crab, marine park, estuary, recruitment, fishing

INTRODUCTION

The benefits of marine parks include reported increases in abundance, growth rates, and average size and recruitment of fish, as well as ecosystem benefits through reduced disturbance (Cole *et al.* 1990; Roberts 1994; Childress 1997; Wahl 1997). Special natural features can be protected, providing ecosystem maintenance and ensuring long-term sustainability (Agardy 1997). Tourism, particularly fishing, is a major cause of concern with its impact on certain parts of the marine system (Russell 1996). To minimise this pressure, closed areas, harvest refugia and multi-use marine protected areas are being implemented to protect the marine environment (Agardy 1997). Closed areas or harvest refugia aim to conserve stocks and habitats threatened by over-exploitation and destructive fishing, whereas multi-use marine protected areas safeguard critical habitats while allowing the long-term, sustainable use of marine resources.

Marine park managers need to be able to demonstrate whether the objectives of the different zoning schemes are being met. This can be achieved by demographic studies of differences in abundance, size class, sex ratio and recruitment of indicator species between areas. Ideally, indicator species should be readily caught, taxonomically distinctive, relatively abundant, ecologically significant and, preferably, of direct recreational and commercial importance. For example, in comparing coral trout (*Plectropomus leopardus*) from Bramble Reef in the northern Central Section of the Great Barrier Reef Marine Park, Russell (1996) demonstrated that populations react to opening and closing of marine reserves to fishing. Closure led to an increase in abundance and size class with a rapid depletion of stock when the reef was re-opened to fishing. In a study within a Caribbean marine reserve, Roberts (1994) found that the abundance and mean size of commercial species of fish was greater in protected areas than in adjacent fished areas.

The Solitary Islands Marine Park, mid north coast, New South Wales (NSW), Australia (29°52'16"S,153°16'06"E), was declared in 1998. It is the first and largest Marine Park in NSW. Its primary aim is to protect representative examples of marine diversity, while catering for a broad range of recreational and commercial activities (MPA 2002). The Wooli Estuary is in the north of the SIMP, with different zones implemented to allow continued commercial and recreational use in some areas while ensuring a sustainable future for fisheries in the SIMP. A Sanctuary Zone was designated in the upper reaches to protect species from fishing and provide a recruitment source to the fished Recreation Zone in the lower estuary (Fig. 1). To determine the effectiveness of these zones in the Wooli Estuary, the mud crab (*Scylla serrata*) was identified as a potential indicator species. Not only is the crab targeted by commercial and recreational fishers, it is large, easily identified, and plays a key role as a predator in the estuarine food web (Hill 1979).

The primary objective of the study was to evaluate the effectiveness of the Sanctuary Zone by comparing the abundance and demographic structure of mud crab populations between the adjacent fished and unfished zones. We hypothesised that if the zoning was currently effective, there should be significantly more crabs in the Sanctuary Zone and the median size class of crabs in the fished Recreation Zone would be smaller owing to the selective harvesting of larger individuals. If the Sanctuary Zone is acting as a 'source' population, there should be a significant number of large crabs recruiting from the Sanctuary Zone to the Recreation Zone.

Study area

The Wooli Estuary is within the SIMP on the NSW mid-north coast (29°52'16"S,153°16'06"E). The Wooli Estuary is a highly infilled barrier estuary with a water area of 1.9 km^2 (Roy *et al.* 2001). The entrance is open and trained by two erected rock walls. Vegetation includes mangroves (0.493 km^2), seagrass (0.028 km^2) and saltmarsh (0.531 km^2) (Roy *et al.* 2001). The substratum throughout the river is sand in the lower reaches and mud in the upper reaches. The water in the upper reaches is tannin-stained most of the time and throughout the estuary during periods of flooding. The estuary is divided into two management zones providing for recreational activities (Recreation Zone) from the mouth to 9 km upstream and full habitat protection (Sanctuary Zone), upstream of this point (Fig. 1).

The Wooli River catchment (190 km^2) includes timbered belts in the upper reaches, and swamps, wetlands, tidal marshes and dune areas in the lower catchment (Stone 1999). The land uses in the Wooli River catchment are Crown land (grazing), National Park and State Forests. The adjacent village of Wooli is a coastal fishing village (pop. 500) with a commercial fishing fleet capturing finfish and crustaceans. Before the SIMP was declared, the river was harvested by commercial fishers for mud crabs, but the decline in mud crabs led to a reduced commercial effort. The Wooli region is increasingly popular as a destination for tourism, of which recreational fishing, particularly for mud crabs, is a major component.

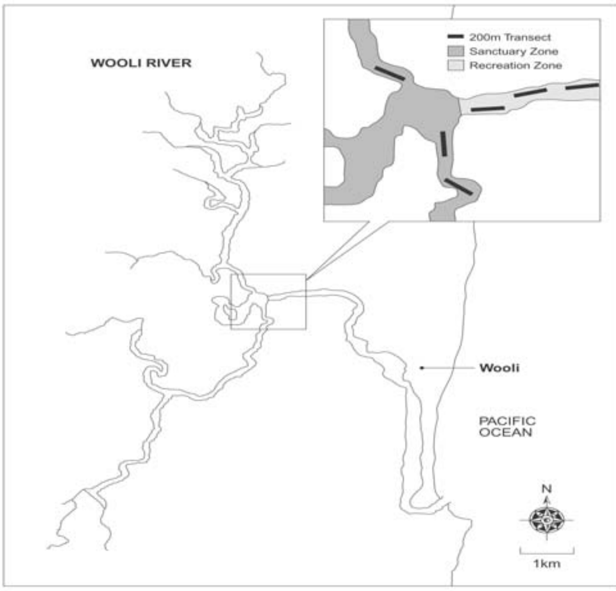

Fig. 1. Location of the study sites at the junction of the Sanctuary and Recreation zones in the Wooli Estuary, Solitary Islands Marine Park.

METHODS

Field

As this aspect of research focused on abundance and recruitment, two study sites were selected either side of the junction of the Sanctuary Zone (Site 1) and the Recreation Zone (Site 2), 9 km upstream from the mouth of the estuary (Fig. 1). Site location was justified from a pilot study conducted in December 1998 which found there to be no difference in crab abundance between the northern and southern arms of the Wooli estuary Sanctuary Zone, while there were significantly more crabs in the Sanctuary Zone than the Recreation Zone. The sites, 300 m apart, were divided into three 200 m transects within 1 km of the junction of the zone border. As the width of the estuary varies from 20 to 30 m within the study site, each transect was randomly placed parallel to the shore with 3 traps per transect to provide nine traps per site. One trap was placed every 100 m in each transect because Williams *et al.* (1982) reported competition between traps at distances <100 m. Each transect was sampled for three consecutive nights, monthly from December 1998 to June 2002.

Mud crabs were captured in commercially designed pots (900 mm x 600 x 300) covered in 20 mm wire mesh because all size classes of crabs were targeted. Each trap had two entrances (250 x 90 mm). Pots were baited with snapper (*Pagrus auratus*), mullet (*Mugil cephalus*) and silver perch (*Bidyanus bidyanus*) and left in the water for 24 h. Captured crabs were sexed, measured for carapace width and length, and tagged with TBA-2 anchor t-tags. Tags were inserted to the right of the abdominal artery where the abdomen and carapace meet, because this junction splits during moulting, reducing the chance of tag loss while preventing harm to the crab. Crabs were released at the capture site. Any crab that was recaptured at the same site within the three-night sampling period was noted but omitted from the results. Captures were compared for overall abundance, size class and recruitment between the Sanctuary Zone and Recreation Zone.

As recreational fishing effort occurred during the study, tags or tag identification numbers from recaptured crabs were collected from recreational fishers to determine whether recruitment was occurring from the adjacent Sanctuary Zone. Recreational fishers returned the tag or recorded the tag number with the, approximate location, date, sex and carapace width and length of each crab.

Crabs were allocated to three size classes for comparison. As Heasman (1980) found that the mud crab moulted into adult body form at 140–160 mm carapace width, adult crabs were considered to be those of 150 mm or more, sub-adults had a carapace width of 100–149 mm, and juveniles had carapace widths of 99 mm or less.

Data analysis

The data were initially tested for normality on a Wilk–Shapiro/Rankit Plot to determine whether the variables conformed to a normal distribution (<0.8). Measures of abundance (catch per unit effort) were compared between zones by analysis-of-variance (ANOVA). Normally distributed data were tested by parametric one-way ANOVA, followed by post hoc (Tukey's HSD) pairwise comparison-of-means test with a rejection level of 0.05. This is a useful post hoc test that controls the experimentwise-error-rate while retaining strong power (Analytical Software 1996).

The Kolmogorov–Smirnov test was used to detect any differences in the distributions of crabs caught between the Sanctuary and Recreation zones. This test is sensitive to any differences between the size-class distributions, including differences in means and variances within classes (Analytical Software 1996). All statistical analyses used Statistix (Analytical Software 1996).

RESULTS

Abundance and size

More crabs were caught per unit effort in the Sanctuary Zone than in the Recreation Zone for all months pooled ($F_{5,17}$ = 13.12, P = 0.0002) (Fig. 2). There were significantly more adult ($F_{1,5}$ = 43.01, P = 0.0028), sub-adult ($F_{1,5}$ = 97.16, P = 0.0006), and juvenile ($F_{1,5}$ = 18, P = 0.0132) crabs caught per unit effort in the Sanctuary Zone than the Recreation Zone (Fig. 2).

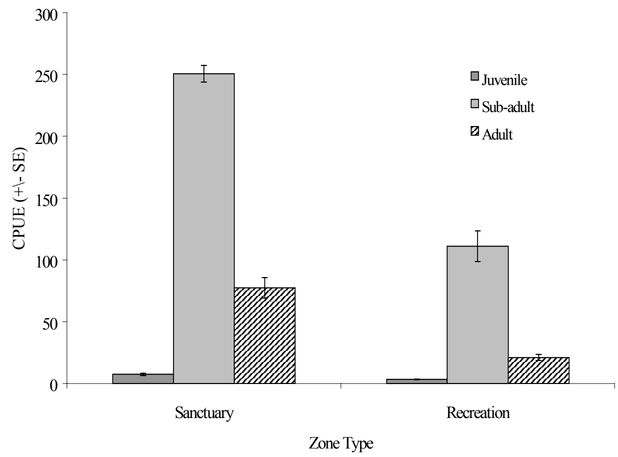

Fig. 2. Mean number of crabs (+/- SE) of different size classes caught per unit effort at each site for all months pooled, Wooli Estuary, NSW. (CPUE = 360 pot nights)

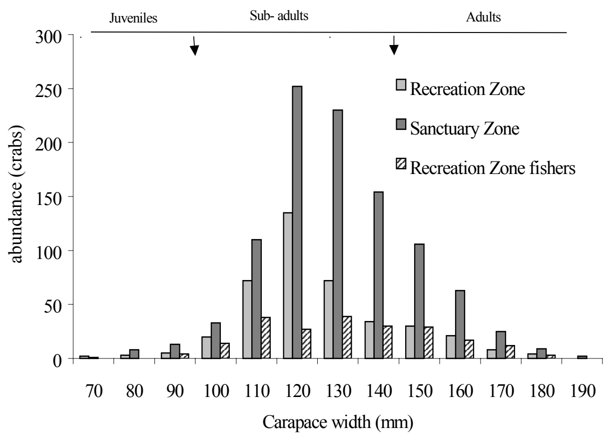

Fig. 3. Abundance by size class for mud crabs tagged in the Sanctuary Zone (n = 1006) or Recreation Zone (n = 406), and for crabs recaptured by fishers in the Recreation Zone (n = 213)

SIZE-CLASS DISTRIBUTION

Actual abundance

The mean carapace width of mud crabs in the Recreation Zone (123.6 mm) was smaller than those in the Sanctuary Zone (136.2 mm). Crabs of 120–170 mm carapace width were more abundant in the Sanctuary Zone than in the Recreation Zone (Fig. 3). Most of the crabs in each zone were in the 120 mm range. The range of actual sizes caught by recreational fishers varied from small sub-adult crabs (100 mm) to large adult crabs (180 mm) suggesting that illegal-size crabs were being caught by some fishers. This was defined from actual tag returns. For crabs to be legally taken by recreational fishers in NSW, they have to have a carapace length of 85 mm (carapace width 128 mm).

Proportion abundance

Overall, the size-class distribution of mud crabs was similar between the Sanctuary Zone and the Recreation Zone (Kolmogorov–Smirnov KS = 0.18, P = 0.1086). However, there were some notable differences in distributions between the size ranges. The Recreation Zone had a larger proportion of crabs between the range of 70–120 mm while the Sanctuary Zone had a greater proportion of crabs in the 130–170 mm size range (Fig. 4). In the Recreation Zone, the distribution was skewed to the left by the larger percentage of smaller sub-adults that were caught and the lack of adult crabs. Equal proportions of larger sub-adult and adult crabs were taken from the Recreation Zone by fishers.

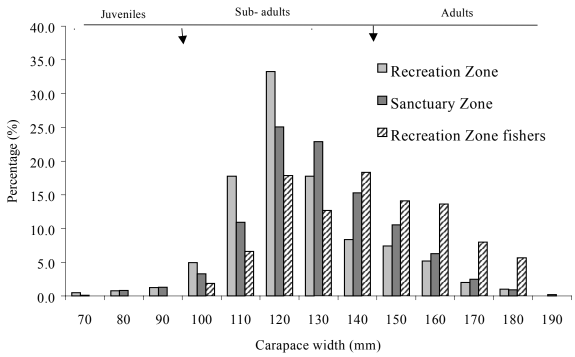

Fig. 4. Size class proportion distribution for mud crabs tagged in the Sanctuary Zone (n = 1006) or Recreation Zone (n = 406), and for Recreation Zone returns from fishers (n = 213).

Movement

In total, 150 (10.6%) of the 1412 tagged crabs were recaptured during the study. A further 213 (15%) crabs were recaptured by recreational fishers in the Recreation Zone (Fig. 5). The Recreation Zone had the higher recapture rate and 11% of the 1006 crabs tagged in the Sanctuary Zone were caught after they had recruited into the Recreation Zone. There was also some recruitment of crabs from the Recreation Zone into the Sanctuary Zone.

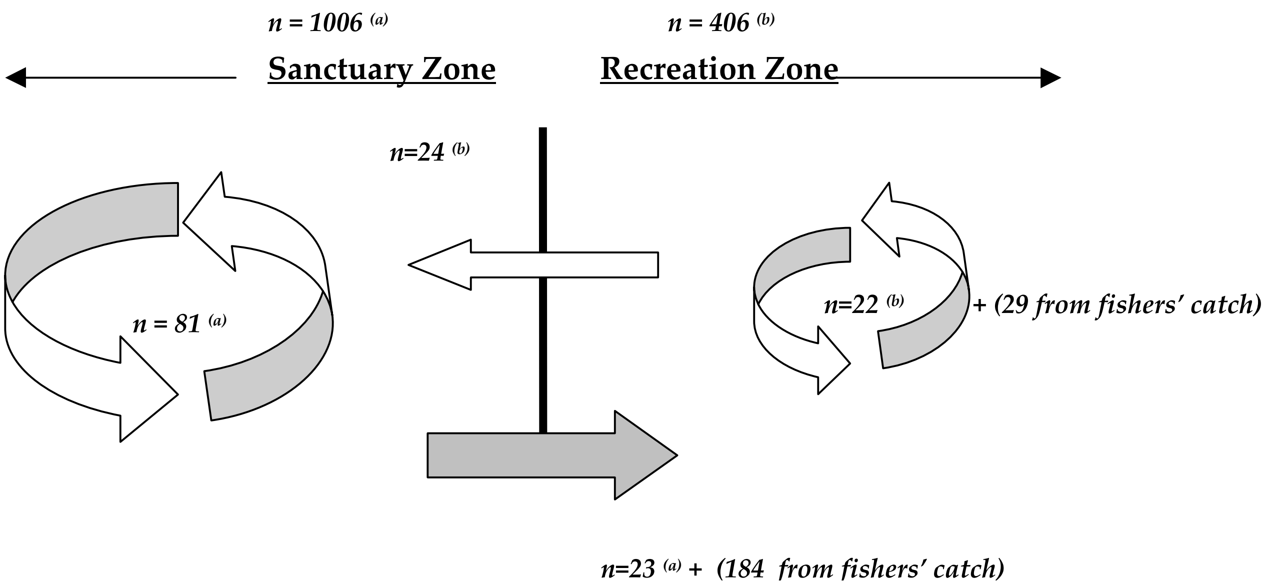

Fig. 5. Movement of crabs; arrows indicate whether they were recaptured in the release zone or in the adjacent zone.

[a]crabs that were originally released in the Sanctuary Zone.

[b]crabs that were originally released in the Recreation Zone.

DISCUSSION

Effectiveness of zoning: abundance of mud crabs

The hypothesis that there would be more crabs in the Sanctuary Zone than in the Recreation Zone in the Wooli Estuary was supported. The catch per unit effort was two-and-a-half times higher in the Sanctuary Zone than in the Recreation Zone. This suggests that the Sanctuary Zone is providing some refuge for mud crabs from exploitation. This finding parallels others where differences have been observed between fished and unfished areas. Roberts (1994) reported that a protected Caribbean Marine Reserve showed an increase in abundance and size class of commercially caught fish species but no difference in population structure of species that were not commercially sought. This suggests that targeted species such as mud crabs will successfully indicate the effectiveness of marine park Sanctuary zones.

Size-class distribution and fishing selectivity

It was predicted that there would be different size-class structures between the two marine park zones, but that, overall, sub-adult and adult crabs would dominate the estuary. If zoning was effective, and extensive illegal fishing was not occurring in the Sanctuary Zone, juvenile and sub-adult crabs would predominate in the Recreation Zone because of selective capture while adults would be relatively more abundant in the Sanctuary Zone. This prediction was also supported by the study. Sub-adults and adults dominated the Sanctuary Zone whereas small sub-adults were common in the Recreation Zone. Recreational fishing effort is likely to be the main reason why the Recreation Zone had low numbers of adults. Adult crabs are the primary targets for recreational fishers while crabs in the Sanctuary Zone are protected from any such removal.

However, the large sub-adult population in the Sanctuary Zone suggests that there may also be substantial natural mortality of adult crabs (although this does not rule out illegal removal of adult crabs). In a study of mud crabs in Deception Bay, Queensland, Hill *et al.* (1982) found that the habitat preferences of crabs of different size-classes varied. Adult crabs were caught mainly in sub-tidal waters while sub-adults moved into the intertidal zone at high tide to feed and retreated to sub-tidal waters at low tide. As the intertidal zone is only small (2–5 m) in this study, the chance of capturing a crab that moved into the intertidal zone was still high because traps were placed directly along the river bank near the small intertidal zone. Juveniles tend to reside in the mangrove zone (Hill *et al.* 1982) so may be unlikely to be found in the main channel. The sampling methods used in this study did not target juveniles, and a better approximation of juvenile abundances could employ the use of artificial substrata such as roofing tiles (Hill *et al.* 1982) that act as a habitat and provide protection for juvenile mud crabs in the intertidal zone.

Size-class distributions illustrate the structure of a population and reveal patterns of selective capture in fisheries. Tracking changes in size-class distribution over time indicates sustainability of the fishery and the effectiveness of control measures such as size limits and zoning restrictions. In this study, the Recreation Zone had a smaller percentage of adult crabs than the Sanctuary Zone. Although this probably reflects differential fishing pressure between the zones (it is likely that the adult crabs have a lower percentage frequency due to exploitation by recreational fishers), natural habitat selection may also be responsible.

In the Wooli Estuary, the Recreation Zone also maintains a small population of juvenile crabs that, if they remain and grow in the same area, will provide a potential fishery for future years. The dominant sub-adult population in the Recreation Zone is at the bottom end of the size class, with carapace widths in the range 110–130 mm. This suggests that approximately 41% of the crabs caught in the Recreation Zone are of legal size (carapace width 128 mm), whereas recruitment from the Sanctuary Zone of large individuals caught by recreational fishers meant that 74% of those crabs are legal size.

Recruitment: "sources" and "sinks"

Although the Sanctuary Zone may contain higher abundances of harvestable crabs, it is important to fishers that these crabs leave the Sanctuary Zone and are available to the recreational fishery downstream. It was predicted that if the zoning system was successful, there would be an 'over-flow' of large crabs into the Recreation Zone and recruitment of small crabs moving into the Sanctuary Zone from the Recreation Zone. Our study showed that a small proportion of crabs moved readily within and between zones, with a steady movement of crabs into the Recreation Zone being evident from the recaptures by recreational fishers. The fact that few crabs were caught in this study (excluding recreational fishers' returns) in the Recreational Zone suggests that crabs entering the Recreation Zone from the Sanctuary Zone are being removed rapidly by the fishery. Therefore, during periods when crabs may not move downstream, the fishery in the

Recreation Zone will be depleted quickly because there is no source of larger legal-sized crabs.

Typically, mud crabs have a limited range of movement in estuaries, yet there is equal chance of recapture at different locations if habitat conditions are appropriate. Hill (1975) reported that 68% of mud crabs recaptured in two South African estuaries had moved less than 1 km from the site of tagging, with the largest movement being 13.5 km. Hyland *et al.* (1984) also suggested that crabs would move on average between 6.6 km for females and 3.7 km for males in Pumicestone Passage in southern Queensland. The greater distance travelled by females may be due to the spawning response of females which move offshore to extrude eggs (Arriola 1940).

Salinity fluctuations during flooding apparently played a major role in the Wooli Estuary where large flushes of fresh water pushed crabs downstream (Butcher unpub. data). Davenport and Wong (1987) found that adult mud crabs could survive in salinities from 2 to 42 ppt and showed no discriminatory behaviour between salinities in this range. This suggests that salinity may not be the major factor pushing crabs downstream and that factors associated with the flooding such as current, increased turbidity, low dissolved oxygen or changes in food resources may be the reason for movement. In the Wooli Estuary, regular floods benefit the mud crab populations in the Recreation Zone by providing an opportunity for crabs to move downstream without fishing pressure, because there is usually a decline in fishing pressure during this period due to unfavourable fishing conditions. Without this sporadic influx of fresh water, it is likely that the Sanctuary Zone would provide little recruitment into the downstream Recreation Zone.

At any time, movement from the Sanctuary Zone could be a result of crabs moving from an area of high population density to one of low population density. Crabs may gain benefits from moving out of the Sanctuary Zone because the greater foraging capacities and lower intra-specific competition outside would potentially increase fitness with little effort needed for foraging and less competition for habitat space.

During the course of this study, it became evident that the behaviour of the recreational fishers changed to reflect the main source of legal-sized crabs. Thus, it was not uncommon to see 10–30 traps immediately downstream of the border between the zones. Crabs moving from the Sanctuary Zone to the Recreation Zone would run the gauntlet of these traps. As the sampling site was downstream of this area of fishing concentration, this would have contributed to the lower catch in the Recreation Zone. It also highlighted the need to consider the specific topography of sites when establishing protective zones. Natural features such as sandbars may provide buffers against such fishing concentration and allow individuals to move out of the zones more freely.

The high percentage frequency of crabs recaptured in the Recreation Zone and little recruitment back into the Sanctuary Zone suggests that if crabs move from the Sanctuary Zone, there is a high chance that they will be caught by fishers before they move back into the Sanctuary Zone. The migration of females to offshore regions during spawning renders them vulnerable to fishing activity when sanctuary zones only protect populations in the upper reaches of estuaries. Females in the Wooli Estuary need to negotiate 9 km of potential fishing pressure before they reach the ocean to spawn. There is a need to develop management plans to meet the needs of this species. Possible changes in management include establishing a mosaic of zones throughout estuaries to protect species that migrate, because the most common and valuable commercial species in NSW are migrants, few are residents and virtually none are transients (Roy *et al.* 2001). Restrictions on the removal of female mud crabs or spawning closures would give females the opportunity to move throughout rivers without being exploited. There is a need to develop legal size limits in line with other Australian States to remove the temptation of illegally taking crabs across the State border to sell.

CONCLUSION

With management plans for the Solitary Islands Marine Park in their early stages of assessment, information from this research is essential for determining the effectiveness of estuarine zones. If the Sanctuary Zone is too small, the fishery may over-exploit the resource. If it is too large, significant revenue is lost to the local community and the fishery is under-exploited. In this study, significant differences in abundance and size class indicate that mud crabs can be used successfully as an indicator species for the effectiveness of estuarine marine protected areas because the crabs are a target species for fishing.

The results of this study provide marine park managers with data to show the community the environmental and fishery benefits of multi-use parks, ensuring the sustainable future of highly valued species. However, zoning schemes will have credibility only if they show sustained success. It is important to continue monitoring marine ecosystems to identify which species react in a measurable way and how each species reacts to different management regimes. According to the results of the present study, mud crabs and their fishery have benefited from Sanctuary Zone protection; however, other species may not react in the same way. Long-term multi-species monitoring systems may resolve this problem in demonstrating the broad-scale effectiveness of marine park zoning.

ACKNOWLEDGMENTS

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MODELLING THE EFFECT OF INTRODUCING MPAS IN A COMMERCIAL FISHERY: A ROCK LOBSTER EXAMPLE

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Abstract

The effect of introducing a large marine protected area (MPA) into a managed commercial fishery was investigated using a spatially explicit, size-structured model. The stock dynamics approximated the biology of Tasmanian rock lobsters in that adult movement was very limited while larval dispersal was widespread.

If an MPA displaces fishing effort into the area that remained open to fishing, then fishing mortality (*F*) would be expected to rise. The effect of this increase in *F* would depend on the level of stock depletion, with three possible main outcomes:

1. If the population was only lightly depleted and above the level of B_{MSY} then fishing the open areas harder increases the depletion level but renders the stock more productive. Depending on the exact level of depletion and the increase in *F*, a new equilibrium was reached.
2. Highly depleted population, below B_{MSY}; fishing the stock harder depletes it further, making it even less productive, if fishing maintained, leads to a fishery collapse.
3. If stock already close to collapse, then displaced effort would be so ineffective that the MPA could act to increase recruitment levels and make the whole stock relatively more productive.

The model suggested that introducing large MPAs may be harmful without a reduction in catch at least equivalent to that displaced from the MPA. An MPA without concomitant catch reduction could lead to further stock depletion in open regions. This can lead to a new equilibrium or fishery collapse, depending on the level of stock depletion when the MPA was introduced. If the fishery was close to or already collapsed, an MPA was likely to be beneficial to stock recovery because of its contribution to recruitment.

Keywords: modelling, rock lobster, marine protected areas, commercial harvesting, benefits

INTRODUCTION

Marine Protected Areas (MPAs) have been advocated in many circles as an option for fisheries management because of a widely perceived concern over the failure of traditional fisheries-management methods. In addition it is argued that MPAs are needed to protect biodiversity. In Australia the National Representative System of Marine Protected Areas (NRSMPA) is at the centre of the Australian and New Zealand Environment and Conservation Council's (ANZECC 1998) plan to secure the long-term future of Australia's coastal ecosystems. The main focus of this plan is the conservation of biodiversity through a comprehensive, representative and adequate system of MPAs.

As harvest refugia, it is suggested that MPAs offer a range of potential benefits for the management of fisheries. Included are the protection of spawner stock, acting as a source of propagules and/or surplus adults, acting as reference areas against which the effects of fishing may be quantified, and acting as an insurance against the failure of conventional management.

The benefits to fisheries are said to arise out of the return to a more natural population age structure (more large animals), which, by virtue of the relationship between fish size and egg production, increases the reproductive output of the population. An MPA thus acts as a source of eggs and larvae and a source of surplus larger fish that recruit to the fishery adjacent to the MPA.

The number of MPAs established around the world is on the increase, at present around 1300 in more than 100 countries (Roberts and Hawkins 2000). Despite this, only 0.5% of the world's oceans are in MPAs and our understanding of the potential outcomes of MPAs remains largely anecdotal. More research needs to be done before we can clearly describe their effects.

A survey of the literature on the effects of the establishment of MPAs provides clear evidence of the fact that resident fish and other species recover from the impact of exploitation and are both of a larger average size and more abundant in reserves (Ward *et al.* 2001). This is an expected result that has stood up to examination in tropical and temperate waters for a range of different fish and invertebrate species.

More importantly, from a fisheries perspective, it has been shown in some cases that yield in adjacent fisheries improves at a local scale. As an example this has been observed in New Zealand where lobster fishermen target good catches of fish close to the boundary of the Leigh Reserve. Studies in South Africa have shown how the catch per unit effort (CPUE) of reef fish in areas adjacent to the large deHoop Nature Reserve have increased. The study by Russ and Alcala (1994) showed how a small Philippine coral reef fishery was maintained in the presence of an MPA.

The evidence that MPAs function as a source of eggs and larvae is less convincing. There is some evidence that this is a likely outcome for inshore reef fish of a large marine reserve in South Africa, the Tsitsikamma National Park, but generally little else is known of this potential benefit (Tilney *et al.* 1996). A Tasmanian study has suggested that MPAs contribute to egg production in lobster, but the overall impact is small relative to the egg production coming from the whole population around Tasmania (Edgar and Barrett 1999).

In this study we examined the effect of introducing a large MPA into a managed commercial fishery using a spatially explicit, size-structured model. The stock dynamics approximated the biology of Tasmanian rock lobsters (*Jasus edwardsii*), in that adult movement was very limited whereas larval dispersal was widespread. The strategy used to explore the effects of MPAs involved

1. Initiating a stock of numerous populations in an equilibrium, unfished state.
2. Harvesting to deplete the model populations to a known level using selective fishing mortality.
3. Introducing the maximum sustainable harvest rate for the given level of depletion either with or without a large MPA.

The work is part of a larger study examining the effects of MPA as a fisheries management tool, funded by the Fisheries Research Development Corporation of Australia.

SOURCES OF MODEL UNCERTAINTY

Unfortunately, there are aspects to such MPA modelling that are difficult to describe owing to a lack of previous experience or understanding.

The first major source of uncertainty concerns how fishers would respond to having a significant geographical part of a fishery closed to fishing. This equates to uncertainty about fleet dynamics in the presence of large closed areas. Because no information is available and each situation is likely to be unique, the only strategy available for dealing with the problem is to attempt to model a number of alternative fleet responses. Alternatives included distributing effort into available fishing grounds in proportion to the catch already taken from those grounds, distributing effort proportionally into the top 50% of areas for catch from the fishery, and other strategies suggested by the circumstances found in particular fisheries. Distributing displaced effort into remaining areas in proportion to the amount of effort already expended in those areas is the least likely to cause problems for the fishery. Any other strategy that relies on focusing effort into particular areas is more likely to lead to a serial depletion of open areas. Here, only the most conservative scenario is considered: proportional dispersal of displaced effort

The second major source of model uncertainty relates to which stock–recruitment relationship to use. An aim of the larger project, of which this study is a part, is to examine the potential effect of introducing MPAs on the Tasmanian rock lobster and abalone fisheries. However, our understanding of the recruitment processes in these species is limited. We certainly do not know which areas are predominantly sources of larvae and which are predominantly sinks for larvae. It seems quite possible that no area is always one or the other. As with the fleet dynamics, the only option when such unknown processes must be included in a modelling framework is to try a number of options and determine the outcomes contingent on each possibility considered. Alternative stock–recruitment relationships were considered, as well as different arrangements of sources and sinks.

In the work considered here the focus is on rock lobsters. Recruitment is considered on a stock-wide basis, with settlement levels in different areas reflecting the previous yield taken from those areas through the history of the fishery (used as a proxy for productivity). We are not reporting any work on arrangements of sources and sinks of recruitment. It appears intuitively obvious that if the major source of recruitment for a fishery can be found and protected, then there should be benefits for the fishery; and this can easily be confirmed by use of our general model. Some recently published modelling work supports the benefits that may accrue to a fishery if the recruitment sources are protected (Apostolaki *et al.* 2002).

The model developed during this project was deterministic. A stochastic version would be a simple change, but for the purposes of the project objectives the outputs are more clearly defined by keeping the model deterministic. In addition, the inclusion of random variation to the recruitment, settlement, and patterns of fleet dynamics (fishing mortality) would tend to reduce any positive effects that might be shown through the introduction of MPAs. Because the outputs of the modelling generally did not demonstrate positive effects for fisheries from MPAs, in order to make the final conclusions more defensible, efforts have been made to select assumptions that could be considered as biased towards a positive effect of MPAs.

MODEL STRUCTURE

Rock lobsters are rather difficult to age, so the model structure took the following structural form:

- It was size-structured by sex (to allow for the sexual dimorphism of rock lobsters). The size-structured nature of the model permits more realistic population dynamics (size at maturity, recruitment and growth by transition matrix), it permits fishing to be size selective, and it permits predictions about the impacts on the population structure (age-structure could easily be added if required). In the model there were 17 size classes of 10 mm from 25 mm up to 185 mm.
- There was an annual time step to the dynamics of growth, recruitment and mortality. Half of natural mortality was applied, then growth and recruitment occur, followed by any movement between areas. Fishing mortality is then applied and finally the remaining half of natural mortality.
- The model was spatially explicit; any number of populations could be defined, dependent only upon availability of information relating to catch and growth. The coastline may be linear or may connect end-to-end (i.e. an island); this detail has implications for movement and fleet dynamics. The separate areas might be statistical reporting areas or assessment areas or might be completely hypothetical, as with the work reported here.
- Recruitment is deterministic. In the work reported here a Beverton–Holt stock–recruitment relationship was used. Settlement success in an area is dependent upon the total yield taken from each area (taken as a proxy for available productive habitat).
- A single-species approach was used. Species interactions, e.g. between rock lobsters and abalone, are ignored.
- Recruitment is spread across all areas and movement of adults in each time-step is restricted to adjacent areas.

MODELLING STRATEGY

The detailed model of the Tasmanian rock lobster fishery was extremely specific. The conclusions drawn about the potential impacts of introducing no-take MPAs were idiosyncratic to the fishery. Large areas of Tasmania could be closed to rock lobster fishing but because these contribute very little to the fishery they would have no noticeable effect. Other areas are so significant to the fishery that closing them, without reducing catch appropriately, led very quickly to a fishery collapse within the model. The effects of closing areas of intermediate importance depended closely upon the dynamic response of the fleet to the closures. If effort was distributed in proportion to stock availability this could lead to stability (assuming that the closures did not represent more than the present level of rebuilding in the stock). If effort was focussed into only a few areas, this led to their decline, which in turn led to decline in other areas; then the fishery could eventually collapse though a process of serial depletion. Redistributing effort in proportion to stock availability generally led to least fishery damage. However, in reality, it is likely that fishers would not be able to fish in this relatively risk averse manner.

To avoid such idiosyncratic answers to generic questions, the strategy was adopted of a defined set of populations with identical properties of growth, movement, catch history and reproduction, so that the issues of different productivity, different catch histories, unknown fleet dynamics and differential recruitment were removed from consideration. These hypothetical populations could number either 10 or 20 to permit the simple closure of 10% or 5% of the fishery. The conclusions drawn from this simplified, idealized stock are therefore general. Nevertheless, the population dynamics approximate those of rock lobsters living in and around Maria Island on the east coast of Tasmania. Care needs to be taken when considering species with radically different life cycles or biology.

The strategy adopted in the present study was to define ten hypothetical populations each with identical growth and productivity. A growth-transition matrix determined from a rock lobster tagging study conducted in the Maria Island marine reserve on the east coast of Tasmania was used to describe the sexually dimorphic growth of the two sexes (Fig. 1). Males obviously grow much larger and heavier than females.

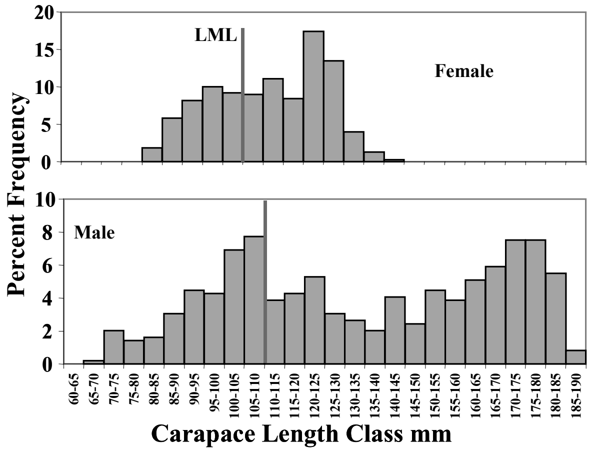

Fig. 1. Carapace lengths (5 mm classes) of rock lobster (*Jasus edwardsii*) captured and tagged in the Maria Island marine reserve after ten years of no commercial fishing. Smaller sizes are present only in low numbers because of the selectivity of the fishing gear. LML is the legal minimum length.

The dynamics of the hypothetical stock of ten populations could be followed through time with or without fishing, and with or without an MPA. By growing the population without fishing the equilibrium levels of recruitment could be defined. Fishing mortality could be imposed on the unfished population and the consequent depletion in biomass and numbers could be monitored. At any stage, the surplus production from the stock could be determined. This would be the catch level that, if applied, would leave the stock at the same productivity level each year (it would leave the population in equilibrium).

By application of a series of different excess levels of fishing pressure, the stock could be depleted to different levels, the surplus production at those depletion levels determined and, in that way, a curve of surplus production against depletion of legal-size biomass determined (Fig. 2). If an MPA was introduced by closing one of the ten hypothetical populations this would be equivalent to reducing the productivity by 10%. The absolute difference this would make to the productivity would be greater near the maximum sustainable yield than when the stock is only lightly depleted (Fig. 2). In addition, the size-distribution of the stock changes with increasing depletion of legal-size biomass in a manner that reflects what has been seen in the real fishery (Fig. 3).

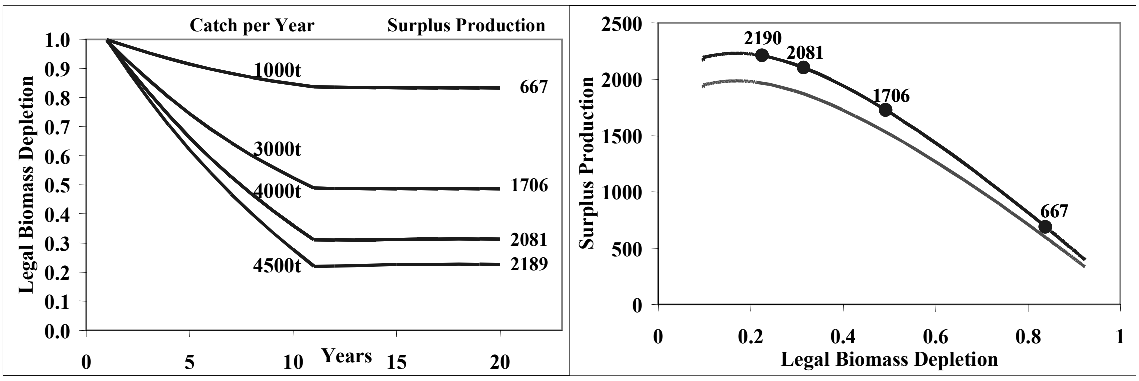

Fig. 2. Hypothetical populations of rock lobster fished at high levels for ten years (catch per year) demonstrate different degrees of stock depletion.

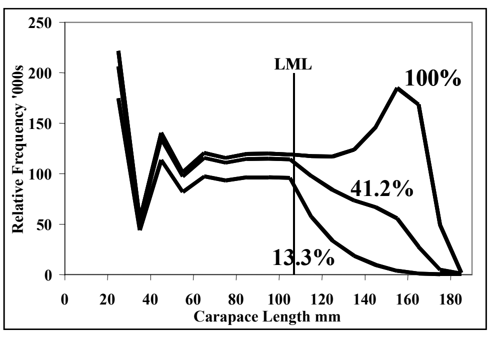

Fig. 3. Changes to the expected size–frequency distribution of male rock lobster at different levels (%) of remaining legal-size biomass (depletion).

Using this model, we investigated the effects on the stock dynamics (both inside and outside closed areas) of introducing a no-take marine reserve equivalent to 10% of the production when the stock was at different levels of depletion.

At each level of stock depletion, there is a catch level that can be maintained through time, defined as the surplus production (Fig. 2, left panel). With different levels of catch per year, the curve of surplus production against stock depletion level can be determined (Fig. 2, right panel). If one of the hypothetical populations is closed to fishing, then the available productivity is immediately reduced to only 90% of the original (lower line in the right panel). The classic surplus-production curve can be seen. The model dynamics become relatively unstable beyond the peak productivity (the Maximum Sustainable Yield). The depletion curve of numbers of animals is more symmetrically shaped around 50% because of the non-linear relationship between size and weight; the larger animals are the first to go, and they weigh the heaviest (Haddon *et al*. unpublished).

The fishing down of the large mode of accumulated older animals is apparent and reflects what has been seen in the fishery on the east coast of Tasmania. The peaks at smaller size classes relate to particular cohorts growing into the population on the yearly time step (Haddon *et al*. unpublished).

RESULTS

Introduction of an MPA when stock is only slightly depleted

When an MPA is introduced (Fig. 4), the available productivity drops from 1200 t to 1090 t. If the Total Allowable Catch (TAC) is not reduced accordingly, the stock needs to be depleted to 62.6% (rather than 67.1%) so that the populations remaining open to fishing can produce the extra catch required (Fig. 4).

A TAC of 1694 t would imply a yield of 169.4 t from each of the ten populations, which would occur sustainably when the stock was depleted to 49.6% of the unfished legal biomass (Fig. 4). If an MPA were introduced, then the nine populations remaining open to fishing would produce only 152.3 t sustainably. To produce the required TAC the stock would have to be depleted to 41.5% of unfished biomass so that the nine remaining populations could produce at a yield of 188.2 t each (Haddon *et al*. unpublished).

In the case of an undepleted stock, the introduction of an MPA leads to a higher fishing mortality outside the MPA and a greater depletion of the stock, but the fishery is still sustainable and the biomass within the MPA increases (Fig. 5).

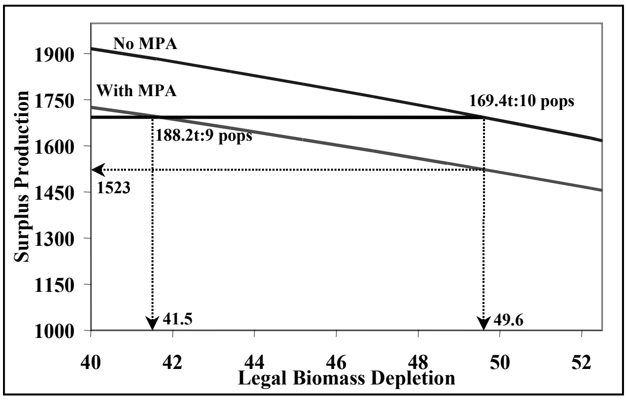

Fig. 4. Impact (modelled) of a marine protected area (MPA) on Total Allowable Catch of rock lobster.

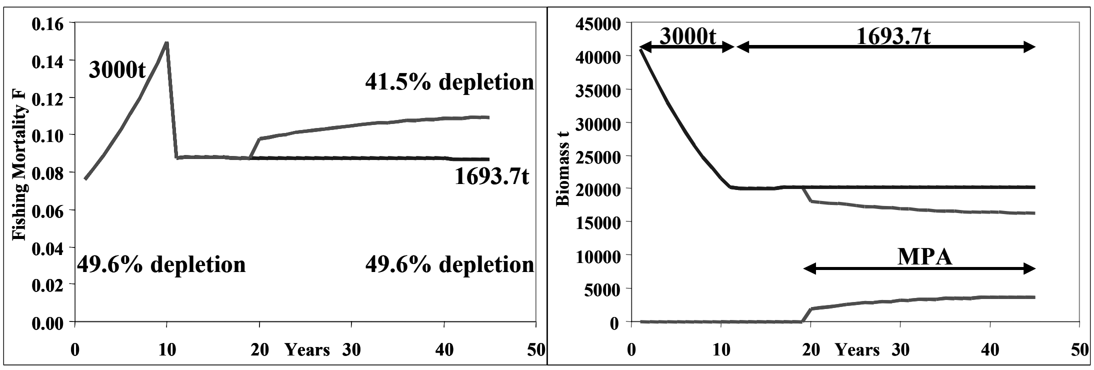

Fig. 5. Impact (modelled) of introducing a marine protected area (MPA) into a rock lobster fishery when it is not yet at maximum productivity, relative to the scenario of no change.

In this case, introduction of an MPA leads to a higher equilibrium level of fishing mortality outside the MPA (Fig. 5, left panel) and a decrease in the legal biomass outside the MPA (Fig. 5, right panel). At the same time, the biomass inside the MPA increases until both inside and outside areas attain a new equilibrium.

Introduction of an MPA when stock is close to maximum production

In the model, if the stock is at a legal biomass near to that which can generate the maximum productivity, then introduction of an MPA enclosing 10% of available production can lead to a fishery collapse, if the TAC is not reduced appropriately (Fig. 6). In the example, with a 30.1% depletion of legal-size biomass the fishery can take 2100 t each year in a sustainable manner. If the MPA is introduced, the nine remaining populations still open to fishing produce only approximately 1900 t sustainably even at the maximum productivity at a depletion level of 17.5%.

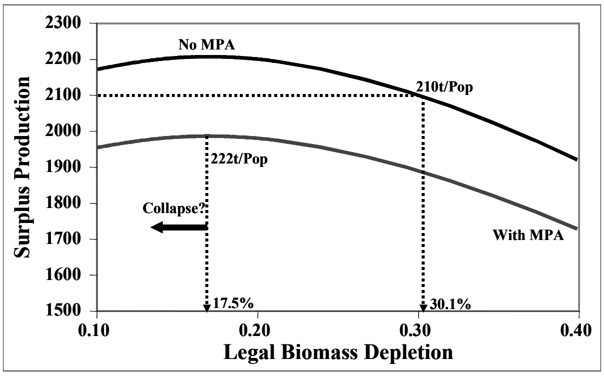

Fig. 6. Impact (modelled) of a marine protected area (MPA) when rock lobster stock is close to maximum production.

However, the strategy of depleting the legal-size biomass further to increase the productivity of the remaining stock can only increase productivity to 1998 t (Fig. 6), leaving a shortfall of 102 t from the TAC. If the TAC is not reduced, then this shortfall must come from the stock biomass, depleting the legal-sized biomass below the most productive level. This would mean that the shortfall of surplus production to TAC would become larger and the fishery would proceed to collapse if further changes were not made to the management. The biomass level in the MPA reaches an equilibrium but the in biomass outside the MPA continues to decline and the fishing mortality to increase (Fig. 7). The fishery is no longer operating sustainably. Because the biomass shortfall in the example is relatively small compared with the legal biomass open to fishing, it takes decades for the depletion levels to become critical and therefore this depletion may be difficult to detect in real, wild populations (Fig. 7), especially in the stochastic environment of real populations.

In this case, introducing an MPA leads to a continually increasing level of fishing mortality outside the MPA (Fig. 7, left panel), potentially leading to a fishery collapse. The legal-size biomass outside the MPA (Fig. 7, right panel) declines steadily while the biomass inside the MPA increases and attains a new equilibrium. The time taken for the decline in legal-size biomass (25+ years) means that it might be difficult to detect such changes in wild populations (Haddon *et al*. unpublished).

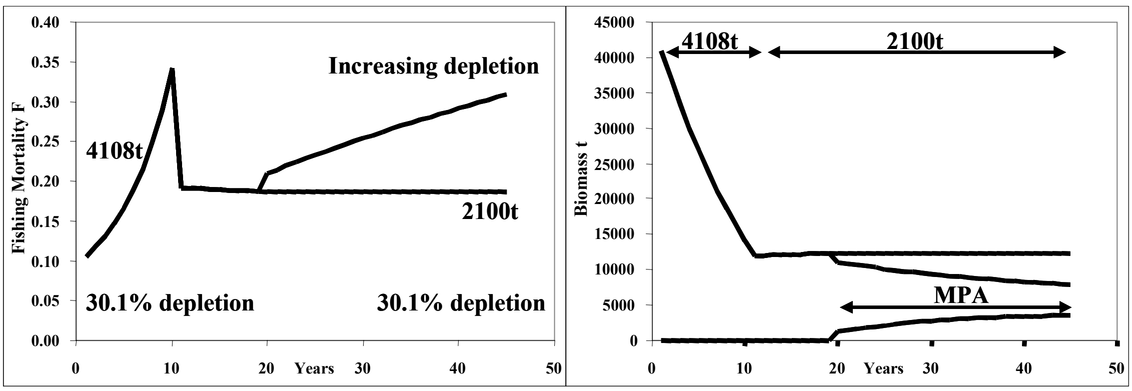

Fig. 7. Impact (modelled) of introducing a marine protected area (MPA) into a rock lobster fishery that is near to its maximum production level, relative to the scenario of no change.

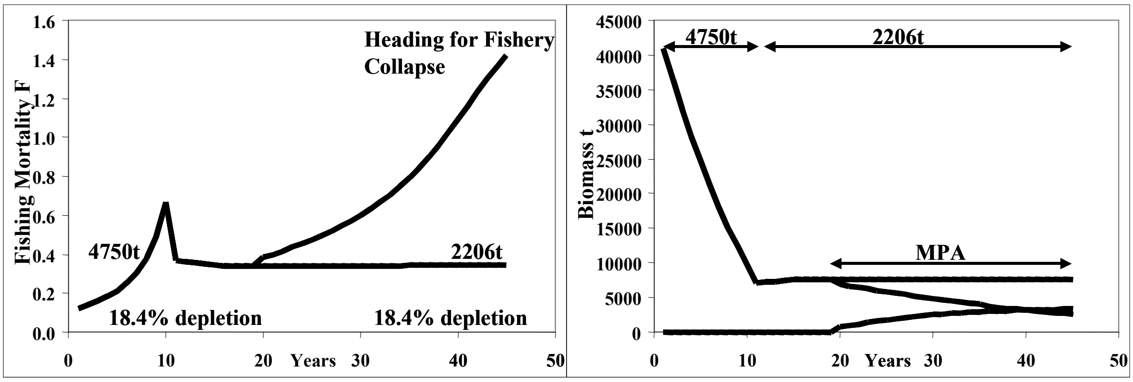

Fig. 8. Impact (modelled) of introducing a marine protected area (MPA) into a rock lobster fishery at or below its maximum production level, relative to the scenario of no change.

Introduction of an MPA when stock is already depleted

If a stock is already depleted to a level at or below the maximum productivity, the impact of introducing an MPA on the dynamics is more immediate and severe than previously seen. This occurs because none of the shortfall in catch can be made up from an increase in productivity brought about by further depleting the legal-size biomass. The legal biomass within the MPA reaches an equilibrium but the legal biomass outside the reserve declines at an increasing rate while the fishing-mortality rate increases in an accelerating fashion until the fishery collapses (Fig. 8).

In such a case, introduction of an MPA leads to a rapidly increasing level of fishing mortality outside the MPA (Fig. 8, left panel), leading to a fishery collapse. The legal-size biomass outside the MPA (Fig. 8, right panel) declines steadily while the biomass inside the MPA increases and attains a new equilibrium. The rate of change of the stock status is rapid relative to the scenarios previously considered. Consequently, it is more likely that these predicted effects could be detected in rela, wild populations.

Effect of movement between population areas

A proportional movement rate of 1% of all size classes between adjacent areas was assumed in all the previous cases. This level would be a relatively generous rate of movement for Tasmanian rock lobster across the boundaries of the statistical catch-reporting area used in the model (Gardner *et al.* in press). Nevertheless, to investigate the importance of movement across reserve boundaries, different proportional rates of movement were examined for their effects (Fig. 9). Because all populations are set equal, when there is no MPA the degree of movement has no nett effect because losses are offset against gains.

In this example (Fig. 9), an MPA is introduced after the population is already in a depleted state (cf. Figs 7 and 8). With no MPA, a sustainable level of catch is achievable leading to a constant fishing mortality. With only 1% movement, a 10% MPA leads to rapidly increasing fishing mortality and fishery collapse. When there is 10% or 30% movement, which is highly unrealistic for other species and southern rock lobster but may be appropriate for some fishes, the depletion rate is greatly reduced and movement towards fishery collapse is greatly slowed, although further depletion of legal-size biomass certainly occurs.

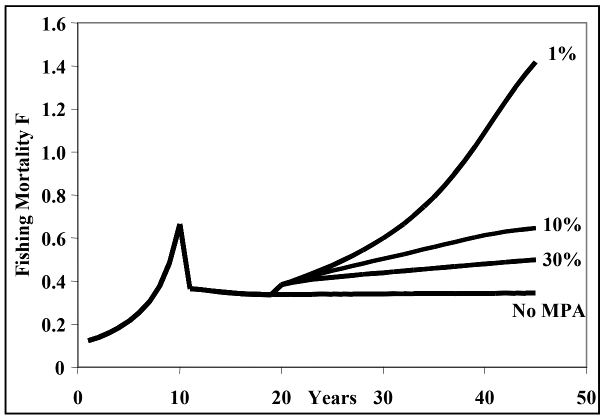

Fig. 9. Effects (modelled) of introducing a marine protected area (MPA) as modified depending on the proportional movement of rock lobsters between population areas.

A high proportion of movement can certainly ameliorate the impacts of an MPA on the remaining fishery. However, this has a negative effect on the success of the MPA (Fig. 10). A high level of movement out of an MPA reduces the effectiveness of the closed area in terms of its ability to increase biomass and produce recruitments. As the proportion of movement increases, the size distribution of animals in the reserve moves towards the size distribution seen in the open areas when there is no MPA. However, there is little impact on the size distribution of animals found in the populations still open to fishing (Fig. 10).

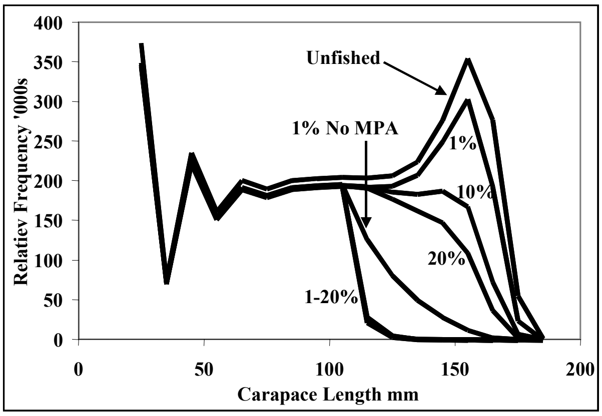

Fig. 10. Effect (modelled) of introducing a marine protected area (MPA) on the size structure of males when a rock lobster stock is already depleted with different proportional movement rates.

With no MPA, the proportion of movement does not affect the final outcome because all populations are equal and gains balance losses. In the unfished state the accumulation of older males leads to a peak of larger animals (Fig. 10). With 1% movement and no MPA, this accumulation is fished down leaving a reduced size structure in which there are still animals up to 150 mm and greater in carapace width. When an MPA is introduced the fishery collapses and the size structure of the open populations is reduced to a remnant just above the legal minimum length. The size distribution within the closed area approximates the unfished distribution. When there is 10% or 20% movement there is hardly any change to the size structure of the fished populations because any fish that leave the reserve are quickly taken in the fishery. However, the size structure in the closed area rapidly depletes away from the unfished levels and moves towards that of the state seen with 1% movement and no MPA. There is still a wider range of sizes available at greater proportions in the MPA but its effectiveness is greatly reduced.

DISCUSSION

The conclusions in this modelling study clearly relate to a specific set of conditions and biological assumptions imposed on the data. Nevertheless, the conclusions drawn are sufficiently general to be applied to other similar fisheries. Of great interest is the fact that the stock depletion that occurs in the populations that remain open may occur at such a slow rate as not to be detectable until stock depletion is far advanced towards fishery collapse. Such slow depletions towards eventual collapse would provide a challenge for any management regime. We observed that when the fishery was in a collapsed state, an MPA might provide a fishery with further catch (albeit a greatly reduced one). However, it is only when the fishery collapses and the biomass inside the reserve becomes similar to the biomass outside the reserve that any positive effects are felt. As a partial step in the recovery from a fishery collapse (along with greatly reduced catches or total closure), there may be some advantages to an MPA. Otherwise, where conventional fishery-management methods were producing positive effects, MPAs produced only negative effects on the fishery. However, if the modelling is continued until the fishery collapses, the modelling is clearly unrealistic. In countries where relevant legislation exists, it is hoped that when signs of imminent fishery collapse became apparent, catch effort is restrained to prevent such an event from occurring. The large MPAs protect against stock collapse but not fishery collapse.

The Tasmanian rock lobster fishery, for example, already has effective limits on effort and catch. There is evidence that the stock has begun to rebuild since the introduction of the quota management system.. In this instance, modelling the fishery indicates that conventional fishery management will lead to a more positive fishery result than could be achieved if large MPAs were introduced.

In summary, because the effects of large MPAs (> 5% coast) tend to become apparent only over many years, the effects of small MPAs (< 0.5% coast) would be hard to detect. Again, because of the dynamics of growth and recruitment, there is a time lag before any positive effects of an MPA become apparent. In an exploited population, introduction of an MPA is equivalent to an increase in the TAC outside the reserve. Introduction of an MPA without a reduction in catch may have a negative effect upon some fisheries. The impact of introducing an MPA will depend on the biology of the species concerned, the state of depletion of the stock, and whether the catch is to be reduced appropriately. If the stock is already in a depleted state, an MPA can hasten fishery collapse.

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ASSESSING AND REPORTING THE PERFORMANCE OF AUSTRALIA'S COMMONWEALTH MARINE PROTECTED AREAS

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Abstract

The Commonwealth Government of Australia has developed a system for assessing and reporting the performance of Commonwealth marine protected areas. Clear reports are integral to the system, which comprises risk assessment, implementation planning, and performance reporting. The system assesses management performance by comparing actual management outputs with clearly defined targets, as well as assessing biophysical performance. The principle aims are to improve management and stakeholder confidence in management. The system is in the early stages of implementation and has not been tested over time.

Keywords: marine protected areas, performance assessment, reporting

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INTRODUCTION

In this paper we present a new performance assessment system to be used by Environment Australia to help manage, and to report on the condition and management of, the twelve Commonwealth marine protected areas under its control. We briefly describe the location, administration and purpose of the twelve marine protected areas. The reasons for implementing the performance assessment system are outlined.

Three component parts of the performance assessment system are described: risk assessment, implementation planning, and performance reporting, with reference to an example - the performance assessment system for the Coringa-Herald Marine National Nature Reserve, a marine protected area about 400 kilometres east of Cairns in the Coral Sea.

MARINE PROTECTED AREAS IN THE COMMONWEALTH JURISDICTION

The Australian Exclusive Economic Zone is the third largest in the world presenting a vast opportunity to find sites for and to declare marine protected areas. This is particularly true of the extensive Commonwealth jurisdiction between three and 200 nautical miles from the coast. It includes Australia's largest marine protected areas: the Great Barrier Reef Marine Park, Macquarie Island Marine Park, and the Great Australian Bight Marine Park. Together with adjacent coastal and terrestrial protected areas, Australia's is one of the most extensive protected area systems in the world.

There are thirteen Australian Commonwealth marine protected areas plus a number of smaller marine protected areas that form part of terrestrial Commonwealth reserves such as Christmas Island The word "Commonwealth" refers to the federal or national level of government. Generally the Commonwealth Government manages offshore marine protected areas (Fig. 1), while State and Territory governments manage marine protected areas within three nautical miles of the coast. The total area of Commonwealth marine protected areas is currently approximately 55 million hectares, including the Great Barrier Reef Marine Park which covers approximately 34 million hectares. Environment Australia, an agency of the Commonwealth Government, manages all Commonwealth marine protected areas *except* the Great Barrier Reef Marine Park, which is managed by a separate statutory authority under an Act of the Commonwealth Parliament. The performance assessment system described in this paper is relevant only to the twelve 'other' Commonwealth marine protected areas; it has no bearing on the management of the Great Barrier Reef Marine Park.

Commonwealth marine protected areas are declared primarily to conserve biodiversity. In many instances, conserving biodiversity does not prevent other uses, such as research, commercial and non-commercial fishing, diving and boating, and nature observation. Although the majority of Commonwealth marine protected areas are a long way offshore, ecologically sustainable uses are allowed if they are compatible with protecting the defined values of those areas.

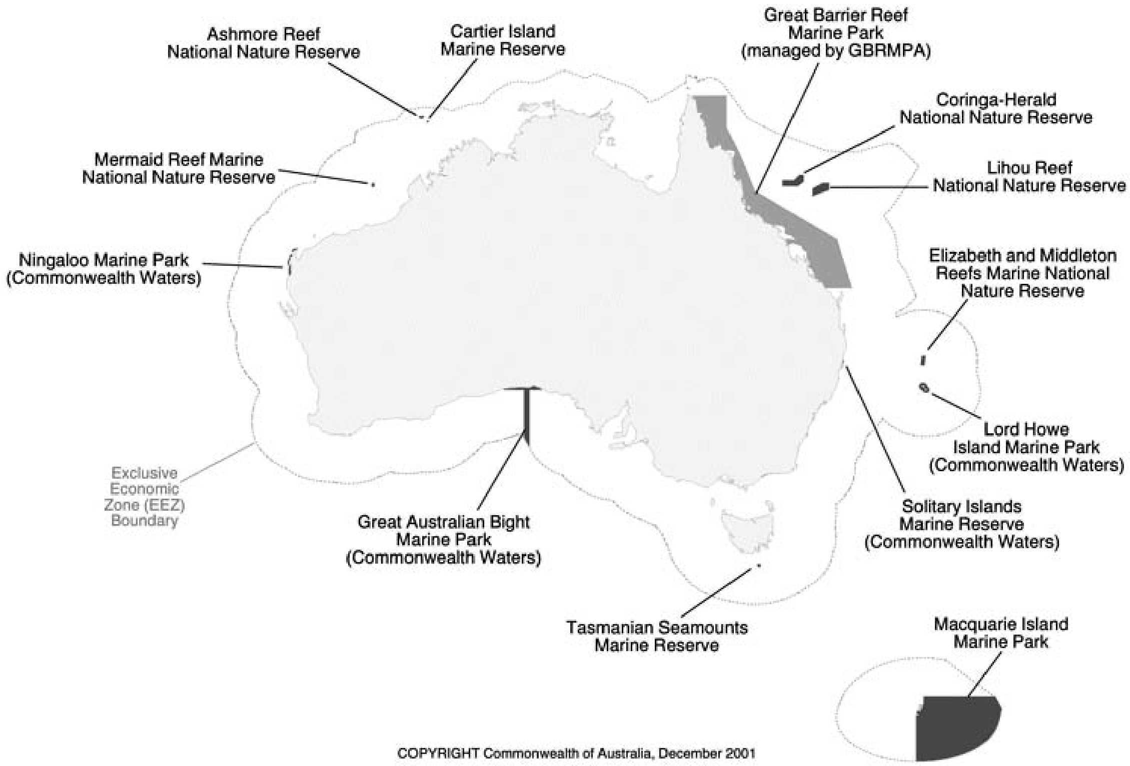

Fig. 1. Commonwealth marine protected areas

ENVIRONMENT AUSTRALIA'S MANAGEMENT ARRANGEMENTS

In addition to managing twelve Commonwealth marine protected areas, the Commonwealth Marine Protected Areas Program [CMPAP] within Environment Australia works to identify and declare new marine protected areas. The Program has developed arrangements with other government agencies like State fisheries and conservation agencies and the Australian Customs Service to provide most of its field operational capability.

Each Commonwealth marine protected area has a legally binding management plan that stipulates what uses are allowed. Program staff developed these management plans in consultation with users and interest groups like the offshore oil and gas industry, conservation groups, and the fishing industry. The management plans operate for seven years once they have been allowed by the Australian Parliament and are reviewed after approximately five years.

The five years prior to the review of each management plan are a convenient period in which to collect information that could usefully inform the review process. However the length of operation of each management plan poses a difficulty when applying that information to fix any problems with the management plan. Since each plan is in force for seven years the remedy has to wait until the scheduled review and preparation of the succeeding management plan, or else the Program has to launch an amendment process prescribed by law, part way through the life of a plan. The cost and length of the statutory amendment process mean it is currently used as a last resort and only for the most significant of problems.

Most of the management plans explicitly require some form of performance assessment. However most management plans lack guidance about how to assess performance, how often to do it, or even how to use the results in evaluating management effectiveness. For example, the plans are silent on whether the performance assessment information is required input for the five-year review of each management plan.

During 2001/02 we developed a performance assessment system to address these gaps, building on existing work and models. This included unpublished internal analyses, strategies developed for Environment Australia by a number of contributors over the past two years, and the publications cited at the end of this paper. Our approach is loosely based on work commissioned by the World Conservation Union (IUCN) and the former Australian and New

Zealand Environment Conservation Council (ANZECC). However, the framework also has attributes that allow us to satisfy extra departmental and government reporting requirements.

We include "performance reporting" in our use of the term "performance assessment". In current practice, performance assessment goes beyond the activity of assessing, traditionally the field of ecologists, to include why the assessments are being conducted in the first place; the way in which the assessments are presented and, to whom they are presented.

WHY ASSESS PERFORMANCE?

In areas that are highly protected, environmentally undesirable outcomes are likely to be caused by external influences or natural processes; in other words, causes that cannot be managed. Some managers use this to argue that assessing and reporting performance in highly protected areas are low priorities. However, even if coral bleaching occurs as a result of climate change, it is important to have an estimate of the nature and extent of the problem. Understanding the nature and extent of the problem may be critical to managing other influences that could exacerbate it. Alternatively, this information may also inform decisions about the future of the MPA if it has been declared to conserve very specific values – values that subsequently disappear. It is also necessary to report on the nature and extent of the problem from the point of view of government accountability, because the problem could limit the ability of managers to deliver the outputs promised in a management plan.

To carry this idea one step further, governments are increasingly demanding that their public officials provide clear, accurate descriptions of how they spend public money and the results of that expenditure. Public accountability and peer review of the results of research and monitoring promote a culture of good governance. As mentioned, most of the management plans for Commonwealth marine protected areas commit the government to performance assessment. The CMPAP expects that implementation of a transparent assessment and reporting system will stimulate improvements to our management of marine protected areas.

Interest groups and the general community are paying increasing attention to how natural resources, including marine protected areas, are managed. A common criticism of the Commonwealth is that we place too much emphasis on declaring new marine protected areas, instead of measuring the outcomes of existing ones and ensuring that they are managed efficiently. Many people, quite logically, are unwilling to accept the need for new marine protected areas unless the benefits of existing marine protected areas are demonstrated. The CMPAP expects that implementation of a transparent assessment and reporting system will help improve stakeholder confidence in our management processes.

Consequently the performance assessment system developed by the us aims to:

- optimise co-ordination of, and synergies between, management actions across different marine protected areas in the Commonwealth estate;
- integrate with existing management approaches without losing consistency or quality of output;
- acknowledge the statutory basis of management plans; and
- increase stakeholder support through openness and public accountability.

THREE-STEP SYSTEM FOCUSSING ON PLANNED OUTPUTS

Fundamental to the design of the system is the intention to assess the performance of management processes. There are obvious cost advantages when measuring management outputs as opposed to measuring highly variable marine ecosystems. Nevertheless the monitoring of *some* key biophysical indicators is essential. Ultimately it may be possible to establish clear links between specific management actions, as prescribed in the management plans, and their responses in the marine protected areas. This would be the only way to establish definitively whether management intervention has been effective.

A key feature of logical, transparent and efficient management is that every management activity is directed towards achieving a planned outcome by achieving defined targets that can be measured. Accordingly the system establishes clear links between inputs, outputs, and a set of "planned outcomes" derived from the management plans. There are three main steps: risk assessment, implementation planning, and performance reporting.

The risk assessment is a formal step in the process that establishes "risk ratings" for various threats to the successful management of each marine protected area. In line with typical management practice the risk rating is generated by determining the seriousness of the consequences, if the threat occurred, and the likelihood of it occurring. Risk ratings are used to establish priorities for decision-making. In general, the Program's resources are systematically directed toward producing those management outputs that address higher-risk threats. Risk assessments are routinely updated, to ensure currency in the risk ratings.

Implementation planning is the process of consolidating all the prioritised management actions to be completed in respect of each marine protected area (together with the planned "outputs"), the assignment of targets to each, and where appropriate, a scheduled completion date. For each marine protected area, the list of planned outputs includes all the management actions necessary to monitor key ecological indicators ("outcome indicators"). Thus, the implementation plans document the links between the planned outputs and the planned outcomes, key ecological indicators to be monitored, the relevant text of the management plans, and the associated risk ratings. These plans summarise what management actions are needed to achieve "targets", and what progress has been made to date.

Fig. 2 is an extract from the Implementation Plan for the Coringa-Herald Marine National Nature Reserve, a marine protected area about 400 kilometres east of Cairns in the Coral Sea. The "Planned Outcome" (top of Fig. 2) is typically a specific statement reflecting one of the management goals for the marine protected area. The planned output(s) listed in the left-hand column show what management action is planned in order to achieve each planned outcome. Each "outcome indicator" (shown directly below the Planned Outcome in Fig. 2) is a key ecological indicator monitored to provide a way of measuring success in achieving a planned outcome. Targets are set for each output, which in the example, is one report annually. For ease of reference and reporting purposes, implementation plans show via hyperlinks (not active in the example) the risks addressed and the management strategies captured by the production of each output.

Performance reporting is the process of consolidating information about whether the planned outcomes are being achieved, but in a useful format. Performance reports provide a standard structure for reporting on management progress. They are similar in appearance to implementation plans, but with additional information about achievement of outputs and planned outcomes. Reporting on the outputs that flow from monitoring outcome indicators are intended to provide a measure of the Program's success.

Fig. 3 continues the example from Fig. 2, with an extract from the performance report for the Coringa-Herald Marine National Nature Reserve. In Fig. 3 the Planned Outcome is at the top of the report, as one of the overall goals of the marine protected area. Below it are the Outcome Indicators monitored to measure whether the Planned Outcome is being achieved. Although an assessment of habitat "quality" is subjective, it is adequate for the purposes of the marine protected area in the example because the agency understands the breeding and nesting habitat requirements for the key species. The relevant management Output described in the Implementation Plan (Fig. 2) was an annual report assessing habitat quality. The report then demonstrated that this particular Planned Outcome was achieved, as summarised at the bottom of Fig. 3 in the first paragraph under the heading "Planned Outcome Result". The second paragraph of italicised text shows additional information about other outcomes that are relevant to the Planned Outcome.

Implementation Plan
(Coringa-Herald Marine National Nature Reserve)

Planned Outcome

"Protection of key breeding and nesting habitats for listed species including green turtle and seabirds"

Outcome Indicators:

seabird habitat quality
green turtle habitat quality

Outputs	**Target**	**Achieved?**	**Relevant Mgt Strategies**	**Risk rating**	**Management required to achieve targets**
Report on seabird habitat quality	Annual assessment	Yes	6.1.1; 6.1.2, 6.1.4	Low (2c). Considers 2a, 2j, 3b.	Organise and conduct patrols to facilitate monitoring. Collect data. Data analysed and report prepared.

Fig. 2: Extract from the Implementation Plan for the Coringa-Herald Marine National Nature Reserve

Planned Outcome:

"Protection of key breeding and nesting habitats for listed species including green turtle and seabirds"

Indicators used to measure achievement of Planned Outcome:
Seabird habitat quality

Green turtle habitat quality

Planned Outcome Result:

The quality of key breeding and nesting habitat for indicator species, including turtles and seabirds, is good.

Resulting seabird and turtle nesting success is satisfactory, being consistent with regional trends and the status of the seabird and turtle populations using the reserve is stable, except for frigate birds. Although frigate birds had a declining population, it was consistent with the regional trend for this species and was not restricted to the Reserve.

Fig. 3. Extract of performance report for the Coringa-Herald Marine National Nature Reserve

One of the most significant attributes of the reporting system is the one short document summarising the key biological and management information for each marine protected area. Here "key" information refers to defined indicators such as the population size of an important species, or the presence of a critical habitat and a description of its health. It also refers to incidents of non-compliance and marine pollution, co-operative arrangements with other agencies, and the extent to which management actions have met their targets. This approach allows a manager who is unfamiliar with a marine protected area to quickly view a complete assessment of that area, including which management outputs are the main focus of effort, and why they are. This increases co-ordination across different marine protected areas. It also reduces the management agency's reliance on corporate memory and hard copy files because the reports are relatively short and are stored in easily accessible electronic form.

How much performance assessment is enough?

Prior to the development of this system a persistent question from staff in the CMPAP was "how much is enough performance assessment and reporting, and how is it best achieved?" In practice, budgets are usually restricted and the optimal amount of performance assessment is the amount agencies can afford. However even a very small budget for biophysical assessments is no reason to avoid assessing the performance of management processes.

Cost effective biophysical assessments can be achieved by: using volunteers, developing strategic links with other agencies, using rapid assessment techniques, and accessing the products of remote sensing technology such as satellite imagery. Volunteers provide a key opportunity, but managers must ensure the data generated by volunteers is of a quality that is useful to assessing performance.

It is critically important to select indicators that are clear and cost effective and will stand the test of time; otherwise, the resources dedicated to monitoring those indicators will have been wasted when any decision is made to use a different suite of indicators.

Poor or no reporting is not an option, especially when governments are genuinely interested in working with stakeholders. If no attempt has been made to assess performance, then that must be reported to stakeholders.

CONCLUSIONS

The success of the performance assessment and reporting system is contingent on the completion of a number of critical stages:

- recognition by the management agency of the need for transparent reporting and the allocation of adequate resources to achieve it;
- an assessment of risks as a basis for developing and prioritising management responses (inputs);
- preparation of implementation plans to realise the links between budget planning and planned goals (outcomes), through the definition of management actions (outputs) -

outputs must include reports resulting from monitoring the key ecological indicators;

- completion of the actions (outputs) listed against targets in the implementation plans; and
- preparation of reports concerning output and outcome achievements.

The CMPAP has begun to implement the reporting system as described; this is expected to provide transparent, annual assessments of the status of each marine protected area under its control.

QUESTIONS

It remains to be seen whether the reporting process satisfies the requirements of government and the community. Other questions such as the extent to which the system can be used to assess the performance of the entire Commonwealth MPA estate, for which there exists little biophysical data, also need assessing. However the biggest question is measuring the extent to which environmental performance is related to specific management activities.

APPLYING THE ECO-MANAGEMENT AND AUDIT SCHEME TO ACTIVITIES IN AQUATIC PROTECTED AREAS

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Abstract

The management challenge for Aquatic Protected Areas (APAs) is considered in terms of the European Union's Eco-Management and Audit Scheme (EMAS). EMAS is an environmental auditing system that organisations can adopt on a voluntary basis. It can now be applied in Europe by any organisation that affects the environment. By reviewing the impacts of their own activities, organisations are in a better position to make significant performance improvements. But what if all the organisations and activities taking place in an APA had to conform to the EMAS directive, even scientific organisations? What would be required in terms of management and audit systems?

Given the importance of APAs and the objective of reducing or eliminating negative environmental impacts, a proposal is put forward that all organisations active in APAs should seek EMAS registration. Although this is a hypothetical situation for non-European organisations, EMAS provides a benchmark around which the international APA community could seek performance improvements in the operation of organisations within APAs. Properly administered, this combination will reduce conflicts and social and environmental impacts.

Three steps are involved. First the organisation would have to conduct an environmental review. Second, on the basis of the review the organisation would establish an environmental management system. Third, the organisation's environmental performance would be communicated in an environmental statement that is verified by a third party. This third-party verification is crucial to the external credibility of the performance reported in the environmental statement. The implications of this proposal are explored with reference to the Great Barrier Reef Marine Park Authority.

Keywords: Eco-Management and Audit Scheme (EMAS), Corporate Governance, Great Barrier Reef Marine Protected Area (GBRMPA), environmental management systems, environmental panning

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INTRODUCTION

The management challenge for Aquatic Protected Areas (APAs) is considered in terms of the European Union's Eco-Management and Audit Scheme (EMAS). This scheme is examined for its application to the Great Barrier Reef Marine Park Authority (GBRMPA). Four questions guide the examination. First, does GBRMPA report on its own environmental impacts and, in particular, does this reporting take place through an environmental management system? Second, supposing EMAS applied as the basis for reporting, what would be required of the Authority? Third, would the benefits of adopting EMAS be likely to outweigh the costs? Fourth, what is the relationship between internal governance and regional environmental planning?

To answer these questions, at least at a preliminary level, the annual report and supporting documents of the GBRMPA are evaluated against EMAS requirements.

This evaluation is done on the basis of documents that are available on the GBRMPA web site.[1] The rationale for this approach is based on the need for transparency and accountability and the specific EMAS requirement of a publicly available "environmental statement". In the absence of a *bona fide* environmental statement from GBRMPA, other proxy documents are sought to assess the

[1] Great Barrier Reef Marine Park Authority (GBRMPA) (2002) *Annual Report* and other documents are available at the Authority's website (www.gbrmpa.gov.au). Documents accessed between May and July 2002.

extent to which they address or pertain to the four questions raised. A key point to emphasise at the outset is that GBRMPA is not expected to adopt, let alone comply with, EMAS requirements. GBRMPA is, however, expected to comply with the Ecologically Sustainable Development Guidelines of Section 516A of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Under this section, Commonwealth (i.e. Australian federal) organisations are required to include in their annual reports information on corporate environmental performance (Environment Australia 2002a). The specific provisions of the Act's reporting framework are not reported here in favour of the internationally recognised EMAS. In this regard, the assessment herein is exploratory and constructive with regard to success factors in the implementation and management of APAs. A key point regarding success factors is that there is a relationship between the corporate governance of organisations and regional environmental planning.

Information on the evaluation of corporate environmental performance is diverse and eclectic but increasingly coalescing around environmental auditing, accounting, the specification of measurable criteria, planning targets and timetables (e.g. Gale 1995; Bennett and James 1999; Gale and Stokoe 2001).

QUESTION 1

The first question "Does GBRMPA report on its own environmental impacts and, in particular, does this reporting take place through an environmental management system?" is initially addressed with information from the Annual Report. Following this, comments are provided from the documents on Management Philosophy, Marine Park Management and the draft policy on Environmental Impact Management.

A message from the Authority's Chair introduces the report of operations in the *Annual Report*. This message details the accomplishment of the Authority in terms of the activities of others that threaten the reef ecosystems. One reference to the corporate governance of the Authority states that it "has further improved internal governance". However, no evidence to support this claim is provided. There is no mention of the Authority's impacts on the environment.

The message from the Chair is followed by reports on the Authority's operations, executive operations, key issues, service groups, day-to-day management and financial results. The report on the Authority's operations ranges from descriptions of the enabling legislation—to the operational structure—to external relationships (Table 1).

Table 1. Operational matters concerning the Great Barrier Reef Marine Park Authority

Enabling Legislation
The Minister
Directions of the Authority from the Minister
Goal and Aims
Membership of the Marine Park Authority
Qualifications of Marine Park Authority Members
Commonwealth Authorities and Companies Act 1997
Audit Committee of the Authority
Offices of GBRMPA
Operational Structure
Service Charter
Executive Group
Subsidiaries
Great Barrier Reef Ministerial Council
Great Barrier Reef Consultative Committee

These documents detail the ways in which GRBMPA "is the principal adviser to the Commonwealth Government on the care and development of the Great Barrier Reef Marine Park (GBRMP)" and that the primary obligation and responsibility is "to ensure conservation of the Great Barrier Reef" (GBRMPA 2001). Details of the goals and aims of the Authority are listed and include several matters relating to corporate governance such as integrated management, active leadership, minimisation of administrative costs, and recruitment of high calibre staff. Information on the membership, qualifications, legislative arrangements and office locations is also provided in this overall section. Information on the membership and meeting of the audit committee is provided – a requirement under federal legislation. Business activities of this committee cover the following matters: Annual financial statements; Environmental Management Charge; Asset Disposal Policy; Fraud Control Policy; Enforcement and Prosecution Policy; Development of a Risk Management Plan; Reef HQ funding arrangements; and various internal audit reports. (Information about each of these considerations is not provided in this section of the GBRMPA report).

Information is also provided on the operational structure of the Authority and its executive group. In some respects, this information is not clearly described for the benefit of an external reader. The functional titles of the two executive directors are not included in the chart provided, and the relationships between the four "Critical Issues Groups" (CIGs) and the specific "service groups" are not explained. The overall structure becomes a little clearer in a subsequent section on "performance analysis" of the executive. That section details aspects of the three-year-old organisational structure, noting that "The new operational structure continues to evolve but has proven to be effective and efficient" (GBRMPA 2001). Evidence to support this statement is not provided. The same observation can be made about the sections supplying performance analyses for legal services and for ministerial and parliamentary liaison. Many tasks and activities are reported, but documented evidence is not provided.

Critical issues groups

The CIGs section concerns key issues for the GBRMP and World Heritage Area (WHA). Twenty-four pages of details are provided on the monitoring and management of eight key issues by four CIGs with the view to attaining four broad outcomes (Table 2).

Information for each of the CIGs is organised under headings on strategic direction and performance analysis. One strategic objective requires the Authority to meet its obligations regarding the World Heritage Convention, the Convention on Biological Diversity, CITES, and UNCLOS, but nothing more is said about how this is achieved or verified.

Some internal management initiatives are noted. However, accomplishments are asserted rather than evidence based. For example, a statement is made concerning dugongs that "an effective internal (government staff) and external (public) e-mail reporting network for standing / carcasses was maintained" (GBRMPA 2001) but no evidence is provided to support the claim. Elsewhere, reference is made to a specific GBRMPA requirement "to have regard to protect" indigenous and non-indigenous cultural heritage values and the Authority states work has begun on co-operative management agreements. The magnitude of this challenge, however, is not identified, and no performance benchmarks are identified to measure performance.

Regarding the CIG for Water Quality and Coastal Development, this section largely examines external issues and the research and activities underway in water quality research. The Authority does not provide information on the sources, fates and effects of pollutants from its own sources, the impacts of its activities on coastal development, its own shipping management (including oil spills), hazardous chemical use, or its own responses (if any) to maritime incidents.

The CIG for fisheries describes how the Authority pursues sustainable fisheries objectives consistent with the conservation values of the Great Barrier Reef and WHA. It is externally focused on a range of considerations including ecologically sustainable fishing, the protection of rare and threatened species, critical habitats and representative areas, equitable access that recognises traditional needs, and the integration of fisheries and ecosystem management. Information on the environmental impacts of the Authority's activities pertaining to fisheries is not considered.

The importance of commercial tourism is described in the section on Tourism and Recreation. Under "performance analysis", there are brief descriptive summaries about management planning, moorings management and allocation, reef-wide policy, cruise ships, tourism in protected areas, accreditation and other related considerations. The role of the Authority as an agency that attracts visitors in its own right and may have environmental impacts in this regard is not considered.

Table 2. Key Issues and Critical Issues Groups of the Great Barrier Reef Marine Park Authority

Eight Key Issues	Four Critical Issues Groups	Broad Outcome
• Conservation and biodiversity • World Heritage Status • Water quality • Fisheries • Tourism and recreation • Coastal development • Shipping and ports • Aboriginal and Torres Strait Islander relationships	• Conservation, Biodiversity and World Heritage	• To ensure the world heritage values of GBRMPA are protected
	• Water Quality and Coastal Development	• To maintain and where possible improve the water quality of the Great Barrier Reef World Heritage Area
	• Fisheries	• To achieve sustainable fisheries that do not compromise the values of the Great Barrier Reef Marine Park and the Great Barrier Reef World Heritage Area
	• Tourism and Recreation	• Maximise opportunity for tourism and recreation use of the Marine Park which is ecologically sustainable, equitable and efficient.

Service groups

In addition to a report on the CIGs, twenty-five pages of information cover the accomplishments of the four service groups. As with the CIGs, each service group has a broad associated outcome (Table 3).

The section on the Program Delivery Group reviews permissions granted (permits) for activities related to the GBRMP, development applications (including aquaculture developments), statutory planning projects, Local Marine Advisory Committees, Indigenous Cultural Liaison, and liaison with the Department of Defence. No information is provided about the ways in which these considerations (as relevant) are held to apply to the Authority itself in terms of its environmental impacts on the area.

The next section is about the Information Support Group. The work of this group covers Research and Monitoring Coordination, Information Technology, Information Coordination and Analysis, Library Services, and Training and Advisory Services. Each of these areas is discussed in the annual report in sections called "performance analysis". For example, information is provided about a comprehensive list identified as a "new proactive approach to identifying information needs and setting research priorities for managing the GBRMP[2] and World Heritage Area" (GBRMPA 2001). The location of other sources of information on the condition of the GBRMP and WHA are also provided. The Authority obtains information, research and IT services through outsourcing.

Twenty-two achievements concerning management and support services are listed in the Corporate Services section. One achievement contains the word "environmental" in which a "sound EMC (Environmental Management Charge) compliance framework" was maintained. A second achievement concerns the undertaking of a risk assessment and the development of a risk management plan. This issue of what risks were considered is not discussed. Internal audits were undertaken in the following service areas: Environmental Management Charge, Risk Management, Payroll Services, Revenue, Budget

Table 3. Service Groups of the Great Barrier Reef Marine Park Authority

Service Groups	Broad Outcome
Program Delivery • Planning • Environmental Impact Assessments • Environmental Management Systems (Permits) • Indigenous Culture Liaison • Local Marine Advisory Committees (LMAC)	• Program delivery supports the achievement of the broad outcomes and objectives of the four critical issues programs within the Authority
Information Support Group • Research & Monitoring Coordination • Information Technology • Information Coordination & Analysis • Library Services • Training & Advisory Services	• To ensure the Authority's policies and decisions are based on the best available information and are understood and accepted by all sectors of the community
Corporate Service	• To deliver a management framework and support services that help facilitate the effective functioning of the Authority
Communication & Education Coordination	• Improved Australia-wide profile and community understanding of the GBRMP and GBRWHA and its management

[2]The Great Barrier Reef Marine Park (GBRMP) and Great Barrier Reef World Heritage Area (GBRWHA) are under the authority of the Great Barrier Reef Marine Park Authority (GBRMPA).

Management and Asset Management. There is reference to Arthur Anderson as the professional body that conducted the external audit of the financial statements. No external audits of environmental performance are reported.

The activities of the Communication and Education Coordination service group include publishing, the provision of public information, community education, extension programs, media and public affairs. The group is externally focused and does not appear to report on specific aspects of the Authority's corporate governance.

Day-to-day management program

The next section of the *Annual Report* is about the day-to-day management program. This program involves an agreement between the Commonwealth and Queensland Governments on the management of the GBRMP and WHA. The section on "performance analysis" begins with the statement that: "Assessment of day-to-day management activities undertaken confirms that the Day-to-Day Management Program has achieved the aims of the annual business plan". Evidence to support this claim is not provided. The annual business plan is not available on the web site.

An overview of the day-to-day activities undertaken is provided in a five-page section that covers Compliance and Enforcement, Management of Natural and Cultural Resources, Visitor Facilities and Services, Program Management, and Future Outlook. None of these sections report on matters relating to corporate governance of environmental management issues.

Financial

The next and last section of the report before the appendices is the financial report summary. The relevance of EMAS for GBRMPA can be drawn out in part through an analysis of the Authority's expenditures. The Authority had 167 full-time employee equivalents on 30 June 2001 (GBRMPA 2001). These employees were located at the head office in Townsville and other regional offices (GBRMPA 2001).

Actual expenditures at GBRMPA were AUS$30,733,000 in 2000–2001. A breakdown of these expenditures is provided in the *Annual Report* and summarised here in Table 4. The trends in this Table indicate that actual expenditures were 14% higher than budget for 2000–2001. More significantly perhaps are increases in expenditures in three categories. There was a 79% increase in expenditures over budget for the Water Quality and Coastal Development Output Group, a 58% increase over

Table 4. Financial Report Summary: Great Barrier Reef Marine Park Authority

		Budget 2000–2001	**Actual Expenses 2000–2001**	**Variation**	**Budget 2001-2002**	**Year to Year % Increase**
Output Group 1.1	Conservation, Biodiversity & World Heritage	$1,401,000	$1,455,000	+ $54,000 (+ 4%)	$1,486,000	+ 6
Output Group 1.2	Water Quality & Coastal Development	$1,119,000	$1,658,000	+ $539,000 (+ 48%)	$2,002,000	+ 79
Output Group 1.3	Fisheries	$1,240,000	$1,177,000	- $63,000 (- 5%)	$1,220,000	-1.6
Output Group 1.4	Tourism & Recreation	$706,000	$1,021,000	+ $315,000 (+ 45%)	$1,113,000	+ 58
Output Group 1.5	Park Management	$13,818,000	$16,171,000	+ $2,353,000 (+ 17%)	$15,118,000	+ 9
Output Group 1.6	Information & Park Management	$3,977,000	$4,418,000	+ $441,000 (+11%)	$4,267,000	+7
Output Group 1.7	Communication & Education	$4,595,000	$4,833,000	+ $238,000 (+ 5%)	$6,475,000	+41
Total		$26,856,000	$30,733,000	+ $3,877,000 (+14%)	$31,751,000	+ 18

budget for the Tourism and Recreation Output Group, and a 48% over budget increase in the Communications and Education Group. These cost overruns were met with additional funds, and the Authority secured an increase of 18% over its 2000–2001 budget for the subsequent year.

In addition to the *Annual Report*, it is also important to consider other documents. Two documents noted in the *Annual Report* are of possible interest: the *25-Year Strategic Plan* and the *Business Plan*. However, these documents are not available on the web site. A brief summary of the *25-Year Strategic Plan*, prepared in 1994 is provided and includes the following statement that seems rather implausible:

> "The Strategic Plan gave everyone who has a stake in the Reef's long-term future a say in how the Great Barrier Reef World Heritage Area is to be managed over the next 25 years. This approach will ensure the Reef remains in a healthy state and can be enjoyed by future generations."

Of the readily available documents on the web site, two are particularly relevant: *Management Philosophy* and *Marine Park Management.* A further document, the draft policy on *Environmental Impact Management*, is externally focused and does not report on the environmental impacts of the Authority.

The *Management Philosophy* is important because it specifies four management considerations: management at the ecosystem level; conservation and reasonable use; public participation and community involvement; and monitoring and performance evaluation of management. The first three of these considerations relate directly to external program delivery. Of these, public participation and community involvement is briefly considered under question four. It is the fourth consideration on monitoring and performance evaluation of management that is of particular relevance here. The Authority states:

> "The Authority and its partner agencies operate by establishing and implementing a management regime for the Great Barrier Reef Marine Park and World Heritage Area. This engenders a responsibility to monitor the condition of the managed system and the effectiveness of implementation of the management. The biophysical condition of the Great Barrier Reef Region is addressed by the State of the Great Barrier Reef World Heritage Report. The effectiveness of management is addressed through assessment and reporting of Authority programs and the day-to-day management of the Marine Park."

The last sentence in this statement requires further scrutiny. The conduct of the "assessment" and the "reporting" of management effectiveness are not discussed further. There is some elaboration in the document on *Marine Park Management* on the topic of "management focus" but nothing concerning the "standard" for performance measurement or reporting is mentioned:

> "In March 1998 the Commonwealth Minister for the Environment announced reforms to the administration of the Great Barrier Reef Marine Park Authority. These reforms will result in a more efficient and effective organisation. Implemented in July 1998 the new administrative structure is based upon four critical issue groups, each reflecting a key challenge in protecting and managing the Great Barrier Reef. The Authority will also rationalize its consultative processes so that it is more responsive to the needs of the community and key stakeholders including tourism operators, the fishing industry, and indigenous groups. Conservation of the Great Barrier Reef will continue to be the Authority's primary obligation."

If anything, this paragraph is telling of the pressures the Authority is under concerning the accommodation of commercial uses of the area – including perhaps the accommodation of some incompatible uses, although this is not explicitly stated.

Following the main report, there are seventy-four pages of appendices containing supporting information on financial and other matters. Appendix D, for example, has the title of "Ecologically Sustainable Development and Environmental Performance (*Section 516A Environment Protection And Biodiversity Conservation Act 1999*)". This is a puzzling section. Not only is the term "performance" not mentioned once in the text, but the content of the section has nothing to do with the stated ESD Reporting Guidelines (Environment Australia 2002a). Rather, the section concerns matters such as environmental impact assessment and other sections of the EPBC Act.

Answering Question 1

The extent to which the Authority reports on its own performance of environmental issues is of particular interest in this research. A related consideration is the development and application of an Environmental Management System in response to the identified environmental issues. As far as the various readily available public documents are concerned, there is little in the description of the broad outcomes, strategic objectives and performance analysis that pertains to organisational performance in a measurable way. In other words, there are no reports of performance against specific targets and timeframes. For example, the statement that, "The new operational structure continues to evolve but has proven to be effective and efficient" (GBRMPA 2001) is not benchmarked to a reported standard. The statement may be true, but evidence is not provided. The same observation can be made about the performance analyses sections for legal services, and for ministerial and parliamentary liaison. Many tasks and activities are reported, but there is no information about levels of performance, specific benchmarks (i.e. stated points of departure) or the tracking of performance over time.

On the basis of the information provided, there is no reporting of the environmental impacts of the organisation. In addition, there is no evidence of a corporate environmental management system. A search on the GBRMPA web site for the following terms produced no responses: environmental planning; EMAS; ISO 14000; ISO 14001; Environmental Management System(s); Environmental Auditing; Life Cycle Assessment; Environmental Performance Evaluation; Environmental Labelling; Eco-labelling.[3] Given the absence of environmental performance information, a more pressing issue for the Authority is the requirement of Section 516A of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) that Commonwealth organisations report on this matter (Environment Australia 2002a). The status of this reporting requirement is not mentioned on the web site and the information provided in Appendix D does not document the effects of the Authority's activities on the environment, just one of the reporting requirements set out by Environment Australia (2002a).

QUESTION 2

Turning now to ***the second major question, "Supposing EMAS was applied as the basis for reporting, what would be required of the Authority?"*** An answer to this question requires a description and explanation of key aspects of EMAS, the aim of which is "to promote continuous environmental performance improvements of activities by committing organisations to evaluate and improve their own environmental performance".[4] It allows organisations in the European Union and the European Economic Area to participate on a voluntary basis in an organised environmental management scheme (European Commission 1993, 2001). The relevance of a European initiative to the Australian context is explored under question four.

EMAS became a European Union regulation in 1995. An interesting and innovative feature of the first EMAS regulation was its focus on sites operating industrial activities. This meant that a company could not register on behalf of its subsidiaries. Every registration had to be based on a specific site. The details of the registration require the following corporate initiatives, key aspects of which are discussed in this paper:

1. Adoption of an environmental policy;
2. A policy commitment to continuous improvement;
3. The definition and implementation of an environmental program and environmental management system;
4. Procedures for monitoring and verifying compliance;
5. Environmental audits at corporate sites;
6. Preparation of a periodic site-based Environmental Statement;
7. Independent verification of the Environmental Statement;
8. Public access to the verified statement; and
9. Quantified public statements set at the highest management level.

In April 2001 EMAS was expanded to include all sectors of economic activity, including local authorities (European Commission 2001).[5] As a result of this initiative, public authorities such as the European Commission and regional and local governments can all register to the scheme.

Regarding question two, there are three broad activities that an organisation has to undertake to meet EMAS requirements. First the organisation

[3] The only EMS reference is to the Environmental Management Charge. Searches for the term labelling included the spelling variation 'labeling' and the use of 'environmental' and 'eco' as prefixes.

[4] EMAS information was accessed in June and July 2002 from two European Union web sites: (http://europa.eu.int/comm/environment/emas/index_en.htm http://europa.eu.int/comm/environment/emas/tools/contacts/helpdesk_en.htm).

[5] The revision of EMAS also included the integration of the ISO 14001 Environmental Management System, an EMAS logo, and the strengthening of the environmental statement.

is required to conduct an environmental review to investigate its own interactions with the environment. Second, on the basis of the environmental review, the organisation must establish an environmental management system with the purpose of improving its own environmental performance. Third, the organisation's environmental performance has then to be communicated in an environmental statement that is verified by a third party. The following sections review the implications of each of these requirements for GBRMPA.

Environmental review

Under EMAS, organisations are required to investigate their own interactions with the environment. GBRMPA in this regard would be required to assess the ways in which its activities, products and services are related to environmental issues, impacts and performance, and to describe the entire process of analysis in an "environmental statement". The environmental statement is a particularly important part of the EMAS registration process and must include the following information:[6]

- A description of the organisation and its structure, activities, products and services;
- An assessment of all the significant direct and indirect environmental issues;
- A summary of year-by-year figures on pollutant emissions, waste generation, use of raw materials, energy and water, and noise;
- A presentation of the organisation's environmental policy, programs and management system;
- The deadline for the next statement; and
- The name and accreditation number of the environmental verifier and the date of validation.

Of these six points, GBRMPA addresses only the first. The Authority would thus be required to carry out an initial environmental review to identify its environmental aspects. "Aspects" is the term to denote the ways in which the Authority interacts with the environment through "inputs" and "outputs". It replaces the term "effects" used in environmental impact statements and assessments (and which tends to have a negative connotation). Under EMAS the issue of self-assessment in an environmental review is found wanting. The requirement is for an independently verified environmental review. This is an important stipulation and tackles the issue of biased and unbalanced reporting that often characterises performance reporting in the industrial sector. The environmental review requires an assessment of the following three considerations: the inputs and outputs of the organisation; the laws to which it must comply and performance in this regard; and current management policies. Once the environmental review is completed it does not have to be undertaken again. The review is the basis for the creation of an organisational environmental policy and management system. From this point on, environmental auditing provides the analytical tool for the review process.

Environmental management system

In the conduct of day-to-day activities, organisations have management systems for finance, personnel, and other functions that may include sales, marketing, manufacturing, policy development, and service delivery. These activities are complex and require planned and systematic approaches. A financial system, for example, defines how decisions on expenditures, cash management, budgeting and accounting are made. The delegation of authority, approval processes, and controls for signing cheques are also covered. At a large organisation, the financial management system will require many professional employees and administrative staff.

One typically missing function in organisations is the absence of a system for environmental management. In the 1990s, growing concern about the plethora of informal environmental management systems and the absence of a uniform quality-control process led to the creation of the ISO 14001 certifiable standards for Environmental Management Systems. The ISO work followed the EMAS initiative and innovative standards development in the United Kingdom. Emphasis was placed on an auditable, continuous-improvement management system consisting of the following five major components: environmental policy; planning; implementation and operation; checking and corrective action; and management review. The considerable literature on corporate environmental management systems is now accompanied by local government interest in EMS as a sustainability tool (Bekkering and McCallum 1999).

There is no evidence in GBRMPA's documents, however, to suggest that the Authority has an interest in EMS or a specific corporate environmental policy. To be consistent with ISO 14001, the Authority would have to prepare an

[6] Information from the EMAS Helpdesk accessed in June 2002: (http://europa.eu.int/comm/environment/emas/tools/contacts/helpdesk_en.htm).

environmental policy statement committing it to an auditable system of regulatory compliance, pollution prevention and continuous improvement. The Authority has, of course, inevitably committed to these outcomes in its activities and statements. The step to demonstrate this through an evidence-based system can only lead to improvements in this regard. With a formal process of assessment, many indirect impacts such as purchasing policy can be considered along with more direct impacts such as the management of hazardous chemicals. Environment Australia has provided information on a "Model EMS for Commonwealth Agencies" that although not already under consideration by the Authority is required reading in this regard (Environment Australia 2002b, 2002c)[7].

Third-party verification

An essential aspect of EMAS is the requirement for independent verification of claims. An external agent or agency with accreditation from a recognised Accreditation Body undertakes the verification. The accredited environmental verifier checks that all the necessary elements of the EMS are in place as well as the accuracy and fairness of the information provided in the public environmental statement.

The public environmental statement is particularly important. It is a document published after the initial environmental review and then at intervals of no more than three years according to an environmental auditing process.

Apart from compliance with legislation, the "level" of environmental performance to be achieved is determined by the organisation (often influenced by the organisation's position in the supply chain). There is a difference between EMAS and the ISO 14001 EMS in this regard: EMAS requires a commitment to improvements in environmental performance, whereas ISO 14001 only requires commitments to improving the management system.

[7] The following quotation is from Environment Australia's web site http://www.ea.gov.au/industry/sustainable/ems/ (accessed in June and July 2002): *Environment Australia has developed a "Model" EMS, which individual Commonwealth Agencies can adapt to their own specific requirements. The model EMS incorporates detailed guidance notes and an electronic procedures manual and electronic registers into which Agencies can enter Agency specific information, greatly assisting the development of their EMS. Some Agencies will be able use the Model as either an "off-the-shelf" EMS, others as a prototype for adaptation. We anticipate that this will save you considerable effort and reduce your initial implementation costs.*

Answering Question 2

To meet EMAS requirements for environmental management performance, the Authority would have to undertake an environmental review, have it assessed for accuracy by an accredited environmental verifier, and then design an auditable environmental management system.

QUESTION 3

An answer to the third question ***"Would the benefits of adopting EMAS likely outweigh the costs?"*** may vary according to the economic sector to which it is applied. Some large businesses may argue that the costs of EMAS are too high, a signal that may mask their viability in a sustainable economy. There is also a particular concern about small and medium enterprises. For the purposes of this research, however, the question of benefits is addressed at the level of the overall public good.

Overview of benefits

There is a considerable discussion in the literature about the benefits and costs of EMAS. For the purposes of this study, the information on benefits provided by Environment Australia is sufficient. Environment Australia states that EMS can assist a company in the following ways:[8]

- minimise environmental liabilities;
- maximise the efficient use of resources;
- reduce waste;
- demonstrate a good corporate image;
- build awareness of environmental concern among employees;
- gain a better understanding of the environmental impacts of business activities; and
- increase profit, improving environmental performance, through more efficient operations.

In addition to the above benefits, formalising the tool of environmental auditing is a major process benefit of EMAS. As Frid (1991) states, "Just as a financial audit seeks to assess the ability of an organisation to meet its financial targets, so an environmental audit assesses performance against environmental targets". If the government and industry sectors in the GBRMP, WHA and adjacent areas worked within an EMAS framework there would be a mutually reinforcing framework of benefits.

[8] Information from the Environment Australia web site accessed June and July 2002: (http://www.ea.gov.au/industry/sustainable/ems/).

Third-party certification to a common standard is another process benefit. This approach provides evidence for all concerned that organisations are on the right track in terms of managing the impacts of their activities through a commitment to continuous improvement. EMAS and ISO 14001 represent two different sets of standards in this regard, the latter of which can now be included within the EMAS framework subject to the more demanding requirements of EMAS.

Answering Question 3

The Authority recognises that its structure

> "… must continue to evolve and adjust to adapt to changing circumstances and emerging priorities that are inevitable when dealing with such a dynamic and complex resource as the Great Barrier Reef (GBRMPA 2001)."

This being the case, the Authority may want to consider the benefits of EMS and adopt such a system, initially along the lines noted in the model EMS provided by EA, but also in accordance with EMAS certification. EMAS has the better environmental outcome because auditing is concerned with environmental performance. Under ISO 14001, auditing is not concerned with environmental performance but rather with the management system. To demonstrate leadership within its domain, GBRMPA as a scientific and management agency can further its own goals through the demonstration of management achievement with an evidence-based system of performance evaluation and reporting. It is required under Section 516A of the EPBC Act to report on environmental performance, though to date no readily accessible public information is available that specifically addresses the requirements of this section.

QUESTION 4

The fourth and last question involves the application of EMAS on a regional basis. This question "***What is the relationship between corporate governance and regional environmental planning?***" addresses the interaction between micro-level management systems and macro-level environmental planning. A symbiotic interaction has positive implications for ecologically sustainable development. At the present time, however, many interactions are likely parasitic, with the organisation feeding off the APA in an unsustainable way. It is possible to argue that a management framework that forces operators to judge for themselves (within a supply-chain conformity-assessment process) the "sustainability" of certain businesses creates a more effective environmental-planning framework and more tangible regional benefits. For some business actors, the perception that government is not directly intervening in the economy reduces the sense of "infringement" and the potential for conflict. It is in this sense that the EMS and environmental auditing tools can be considered as market instruments, an area that has received considerable attention in recent years (Gale and Barg 1995). If every organisation within the supply chain of activities in the GBRMP and WHA committed to an EMAS-type system, the directional path towards sustainability outcomes would be more significant than at present.

The relevance of EMAS for GBRMPA

What is important in this appraisal is not the fact that one organisation can benefit from an EMAS-type framework but the broader public-policy consequences of a concerted action involving many organisations. It is the wider systematic implications of a striving by all organisations towards continuous environmental performance improvement that is important, not only because of the direct benefits achieved at the micro-level, but because these benefits require less regulatory intervention from state authorities such as GBRMPA.

With regard to public expenditure, it is not possible within the constraints of this examination to comment extensively on the Authority's budget. However, the 2001 budget increase of 18% may represent a generous increase when compared with other sectors of government spending. Although this increase may be well deserved, no information is provided concerning how the extra appropriation will translate into a higher multiplier in terms of better environment and sustainability outcomes. A key point to note is not the budget expenditures *per se* but that the Authority "is dependent on appropriations for the Parliament for its continued existence and ability to carry out its normal duties (GBRMPA 2001). This economic dependency means that the management of the GBRMP and WHA, and the commitment to sustainability values, depends on the political priorities of the government of the day. A more strategic public-policy approach would be to ensure that actors within the GBRMP and WHA conform to an environmental management standard that is largely self-policed with regard to competitiveness and supply-chain issues. In so far as the standard delivers ecologically sustainable outcomes and that governments still intervene when the need arises, the benefits of this approach are far more likely to exceed the costs. This does not preclude the need for regulation. Case-study evidence concerning the application of economic instruments shows that regulations are essential (Gale and Barg

1995). There is a difference, however, in perception and practice in the application of a regulation as an endpoint in itself versus its application as a framework within which there are "carrots" and "sticks".

This latter point is particularly important as the Authority struggles with its role as a purveyor of values within a large marine ecosystem. A major challenge for the Authority is to ensure that the tourism and commercial fishing industries operate on an ecologically sustainable basis. In the absence of measurable performance achievements, one cannot assume that they do so. A management framework for ecologically sustainable development is required in which there is a considerable amount of responsibility and accountability at the level of each organisation. Conformity assessment to higher standards will be a critical component of this assessment. Tourism is the main commercial industry in the GBRMP, with 1.6 million visitors each year contributing over AUS$1 billion to the Australian economy (GBRMPA 2001). This activity is followed by the fisheries industry at $3 million. Other industries such as shipping also make use of the area. To ensure that these industry sectors and others are ecologically sustainable, each enterprise needs to be considered within a broader management framework than is currently the case. EMAS offers such an approach. More generally, the issue of certifying tourism operators according to ISO 14001 and "ecotourism" standards is one that raises many questions about the compatibility of tourism investment plans with sustainability objectives (Gale 2002).

Answering Question 4

The Authority is concerned with the effective allocation of public expenditures in fulfilling its mandate. In this regard, questions arise about other ways in which a similar or lesser amount of money can be spent to achieve an even more effective outcome. Given the importance of ecologically sustainable development (or no development) in APAs, a proposal is put forward that all organisations active in APAs should seek EMAS registration. This is a hypothetical situation for non-European organisations, but EMAS provides a benchmark around which the international APA community could seek performance improvements in the operation of organisations within APAs. Adoption of EMAS would accord with the Authority's aims for integrated management, active leadership, minimisation of administrative costs, public participation and community involvement. The public Environmental Statement is critical in this regard (and not an ISO 14001 requirement). It is essential for all participants in the APA to understand the strengths and weaknesses of each organisation with regard to environmental and other key performance indicators. EMAS also accords with the aspirations of employees who are increasingly seeking to ensure that their workplace practices are not unwittingly contributing to negative environmental impacts.

The fact that EMAS has European Union origins is not a reason to ignore it. Many European companies registered to EMAS will seek to ensure that a similar conformity assessment process applies elsewhere around the world. Although this does not affect the Authority as such, it may affect industries operating in the area. To date, the EMS focus in Queensland has been on ISO 14001. There is reason to believe that the higher EMAS standard will prove more appealing in the longer term as communities and public authorities seek verifiable improvements in environmental performance rather than mere changes in management systems. EMAS of course is not the last step in the evolution towards sustainability. There is a need for a sustainability management system and auditing process that takes into account social considerations as well as issues pertaining to the environment.

CONCLUSION

A special management system known as the Eco-Management and Audit Scheme (EMAS) represents an important tool for corporate-performance management and regional environmental planning that can be used to manage the impacts of activities in APAs. Its application could be applied to the corporate governance of the authority responsible for the APA as well as to businesses and other organisations operating within the APA.

The major portion of this article has been devoted to the assessment of the GBRMPA's corporate environmental governance. The Authority reports on a large number of tasks and activities, but does not report on its environmental performance in terms of documented evidence, verification, benchmarks, targets and timeframes. This information may of course be available internally within the Authority and not publicised. The absence of publicly available information suggests that GBRMPA's Audit Committee should consider both the availability and accessibility of its environmental performance in some detail. The objective of the committee "to ensure that the Authority maintains a high standard of management, both corporate and financial" (GBRMPA 2001), must be taken to include "environmental" governance. For the Authority to demonstrate its environmental management leadership, the Committee should request its management to prepare and produce an Environmental Statement and encourage other APA organisations to do the same. At the very least, a reassessment of the way in which reporting on Section 516A of the EPBC Act is transacted is essential. The information in the 2000–2001 *Annual Report* does not appear to meet the requirements of the Act.

The case has been made that the EMAS framework will deliver more effective results with less direct regulation and overall public cost. This argument is based on the view that a publicly available conformity assessment process provides a direct and strategic link between corporate internal governance and regional ecosystem-level environmental planning. From the perspective of public policy this relationship – and hence EMAS in this regard – seems to warrant greater attention outside its current European domain.

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POTENTIAL OF VIDEO TECHNIQUES TO MONITOR DIVERSITY, ABUNDANCE AND SIZE OF FISH IN STUDIES OF MARINE PROTECTED AREAS

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Abstract

This paper briefly reviews applications of single-video and stereo-video techniques to help survey fish community composition and relative abundance, and fish length and weight. These techniques have potential application to the initial surveys of candidate habitats for Marine Protected Areas, and to the subsequent monitoring necessary to manage them. Remote video techniques can be used in shelf depths beyond the limits of diver-based Underwater Visual Census (UVC), and stereo-video systems can also be used to complement and enhance normal UVC by allowing very precise and accurate estimates of fish morphometrics (and hence weight). Some video techniques are very cost-effective and can help remove some major sources of observer bias in underwater observations, by removing the need for skilled observers in the field and by allowing simultaneous collection of a much wider suite of information in a permanent record that can be analysed later. This medium is directly accessible to an unlimited audience. Baited, remote video techniques offer a non-intrusive, depth-independent assessment tool with the advantages of both diver-based observation and capture techniques, but appropriate sampling statistics must be developed if relative abundance is to be measured adequately.

Keywords: stereo-video systems, baited video surveys, fish size, fish abundance, monitoring

INTRODUCTION

Fish and fisheries management have been the focus of many Marine Protected Area (MPA) programs – with the expectation that they will "work" by protecting unique or endangered species, maintaining biodiversity in representative areas, restoring degraded habitats, protecting breeding stocks and having a beneficial spill-over effect into adjacent areas (e.g. Sladek-Nowlis and Roberts 1999). Consequently, there has been much research interest in "Rapid Assessment Techniques" for initial surveys and robust monitoring techniques that balance field costs and data quality with the need for very long data series (e.g. Samoilys and Carlos 2000; Samway and Hatton 2001). Underwater Visual Census (UVC) has been the predominant survey tool in studies focussing on shallower coral reefs and temperate rocky reefs. More recently, however, there has been recognition that vast areas of deeper "inter-reef" and shelf habitats inaccessible to research divers are worthy of exploration and conservation, and that important bioregions there should be included in marine reserves (e.g. Pitcher *et al*. 1999). For example, only 6% of the Great Barrier Reef Marine Park is made up of shallow coral reefs, and the remainder below 20 m depth is very poorly surveyed and not included in fishery-independent monitoring programs. On tropical shelves these habitats can be dominated in clearer waters (~50–70 m depths) by phototrophic corals, seagrasses and algae, and in more turbid or deeper waters by filter-feeding gorgonians, sponges, ascidians and bryozoans (McManus 1997). In higher latitudes, kelp and seagrass communities can extend to 50 m, to be replaced by patches and "reefs" of sessile invertebrate communities in lower light regimes (see chapters in Andrew 1999).

With the exception of occasional use of staffed submersibles, UVC of fish communities is not possible in the vast habitats at these depths. Deeper fish surveys have relied mostly on extractive fishing techniques such as trawls, traps and lines depending on seabed topography (Gaudian *et al*. 1995; Newman *et al*. 1997; Wassenberg *et al*. 1997). There have also been promising tests of some video and hydro-acoustic techniques in topographically complex habitats (e.g. Parker *et al.* 1994; Gledhill *et al*. 1996).

At the same time, the image quality of underwater television and video has dramatically improved, whilst its price has plummeted in some forms, and there has been growth in its use in deeper surveys of marine habitats (see Harvey and Cappo 2001 for review). Most pertinent to our paper were the developments of

1. Single or dual baited video or still-camera systems to film deeper-water fish (eg Sainsbury *et al*. 1997; Yau *et al*. 2001), scavengers of by-catch (Hill and Wassenberg 2000) and juvenile predators (Ellis and DeMartini 1995) and fishes inside and outside a marine reserve (Willis *et al*. 2000),
2. stereo-video camera systems to measure free-swimming sharks (Klimley and Brown 1983) and reef fish (Harvey *et al*. 2002a), and to measure length and biomass of fishes in mariculture sorting systems (Petrell *et al*. 1997), and
3. the use of computer vision and neural networks to recognise fish species (Zion *et al*. 1999; Storbeck and Daan 2001).

We are focussing on amalgamating developments on these three fronts to produce depth-independent video tools to harmlessly recognise, count and measure fishes *in situ* in natural and mariculture systems (e.g. Harvey *et al*. 2003; Harman *et al*. 2003). Here we give a selective review of the progress of video techniques in surveying fish biodiversity, and in counting and measuring individuals, with reference to their potential use in the design and monitoring of MPAs.

POTENTIAL BENEFITS OF VIDEO TECHNIQUES IN DETECTING CHANGES INSIDE AND OUTSIDE RESERVES

The preferred option to study the effects of reserves are spatial and temporal comparisons of multiple reserves and control areas, with long-term monitoring (Jones *et al*. 1993; Russ 2002), but suitable contrasts in the amount of disturbance have also been sought or constructed for inclusion in experimental designs (e.g. Campbell *et al*. 2001). The period before an effect becomes apparent depends on the recruitment patterns of particular organisms, their movements and migrations, their longevity, and their interactions with habitats and each other. In general, the most common effects measured have been changes in community structure, and abundance and size of organisms through time, and Jones *et al*. (1993) argue that although focus in studies of marine reserves is usually placed on popular, exploited species, reserve effects may manifest in unforeseen, long-term changes in formerly rare or absent species (or their biotic habitats) not subject to harvesting. Without early information it is impossible to chronicle these changes.

There are two recent developments in video techniques that can play a role in making these measurements and widening the focus of fish monitoring studies – swimmable stereo-video systems to enhance UVC, and remote baited and unbaited video systems deployed to offer video surveillance of fish communities without the presence of a diver.

SWIMMABLE VIDEO TOOLS TO ENHANCE UVC

Underwater visual census has been a successful first choice as a sampling method in many studies of the effects of MPAs (see Russ 2002 for reviews). Jones *et al*. (1993) recommend that the variables that may be measured in UVC fall along a continuum of increasing effort, cost and sensitivity – from simply recording the presence or absence of an organism, to allocating it to an abundance category, to estimating its density per area of substratum, to estimating its size. They note that compromises must be made in UVC between the quantity of information (e.g. the number of species sampled) and its quality. Estimation of sampling area is also inherent in the complex tasks undertaken simultaneously by the SCUBA observer. Consequently, the highest levels of data collection in UVC rely heavily on relatively few specialist fish researchers who must repeatedly calibrate their performance to avoid the numerous, known sources of observer bias (see Thompson and Mapstone 1997; Kulbicki 1998; Watson *et al.* 1995 for examples).

We believe it is desirable and feasible to remove this observer bias and extend monitoring programs to less specialised staff associated with MPAs, by overcoming the need for specialist observers, by automating as many of their data-collection tasks as possible, and by providing permanent video records of their entire sample. These records allow better standardisation of data collection over long time series and can be revisited repeatedly by other observers. Short segments of footage, or still-frame grabs, of the habitats and fauna therein can be mounted in Geographic Information Systems (GIS) to provide visual tools for joint decision making by marine stakeholders and managers in selecting reserve areas, and for scientists to visually portray results of their monitoring to an unlimited audience via the Internet.

Estimates of fish size are important for detecting recruitment events, for estimating fish growth and weight, and for following cohorts through time inside and outside marine reserves (Russ 2002). In this regard, the development by Shortis and Harvey (1998) of a swimmable stereo-video system to measure fish size, range and bearing anywhere in the field of view, and transect width, could considerably improve the performance of UVC. Underwater stereo-video systems have known, fixed focal lengths, and known distances of separation and angles of convergence of the cameras. Calibration cubes are employed to determine the three-dimensional orientations of both cameras and subjects in the fields of view. The geometric principles of airborne topographic mapping are then applied in measuring fish lengths in paired, synchronised video images (see Harvey and Shortis 1998; Harvey *et al*. 2001a, 2001b, 2002a, 2002b). Customised software has been designed to provide these measurements (VMS – see www.geomsoft.com.au) and is featured in Harvey and Cappo (2001).

Theoretical and empirical tests of such systems are now appearing in the literature (see Harvey *et al*. 2002a for review). Whereas the system of Petrell *et al*. (1997) could measure the fork length of anaesthetised salmon to within 3.0% of known length, recent improvements by Harvey *et al*. (2003) produced estimates of free-swimming southern bluefin tuna length within 0.5% of on-deck measurements of the same fish.

In the case of UVC to monitor fish populations, Harvey *et al*. (2001a, 2001b, 2002a) showed that under optimal conditions divers' estimates of model fish size were accurate (mean error = 0.87 cm) but lacked precision (mean S.D. = 5.29 cm), which greatly reduced the statistical "power" (*sensu* Peterman 1990) of their sampling to detect changes in fish length. Significant improvements in accuracy and precision were provided by a stereo-video system (mean error –0.6 cm).

Given a 10% chance of mistakenly retaining a null hypothesis of no difference (a power of 90%), a stereo-video system detected a 15% (~5 cm) difference in the mean length of blue cod (*Parapercis colias*) in New Zealand with 63% fewer samples than those required by experienced divers (Harvey *et al.* 2001b), saving both time and money in visual surveys for this sedentary species. With modification of the angles of convergence and distance of separation of the cameras, such systems can potentially measure very large animals (e.g. whale sharks) and very small fish (including new recruits), as well as rugosity and other parameters of the underlying physical habitat (Doucette *et al*. 2002). Progressive scan cameras must be employed for swimmable stereo-systems, rather than the common interlaced scanning systems, to avoid blurring of imagery by movement of both target and camera.

Unlike swimmable stereo-video systems, single video cameras cannot be used to routinely measure fish in UVC. Stationary single-video systems can provide accurate measurement opportunities only if the subject is swimming in precisely the same plane as a calibration scale, and perpendicular to the camera. This has allowed measurement of abyssal grenadiers and detected significant differences inside and outside reserves in length of shallow-water fishes such as snapper (*Pagrus auratus*) (e.g. Priede *et al*. 1994; Willis and Babcock 2000). However, recent trials in the full envelope of ranges and angles of subject orientation by Harvey *et al.* (2002b) showed the length estimates from both digital and Hi8 stereo-video systems were substantially more accurate and precise than those obtained by single video camera systems. The best mean measurement error (13.62 ± 1.41 mm) with use of a single camera in that study was similar to that reported by Willis and Babcock (2000) of 16.9 ± 2.4 mm. In contrast, the digital stereo-video system consistently produced a mean error of only 0.22 mm, or 0.05% of target lengths, and had the great advantage that the position (range, bearing, height) and orientation of a fish target could be measured directly, anywhere in the field of stereo coverage (Harvey *et al*. 2002b).

Fish swimming speed can also be measured with the data available from stereo-video (Petrell *et al.* 1997) and, with more image analysis, a three-dimensional half-model of each fish can be constructed – allowing weight and volume to be accurately and precisely measured. Accurate estimation of weight from video image area is being tested for applications in industrial-scale fish processing (e.g. Storbeck and Daan 2001), and Zion *et al*. (1999) reported correlation coefficients between fish mass and fish image area ranging from 0.954 to 0.986 for three cultured species. The estimation of length alone, or with body depth also, can accurately estimate individual fish weights from published regressions (e.g. Santos *et al*. 2002). Advances in fish species recognition through the use of computer vision and artificial neural networks are also worthy of consideration in future development of swimmable video techniques to enhance UVC (Storbeck and Daan 2001).

Finally, the majority of observers in UVC employing strip transect or point counts do not physically mark the boundary of their sample unit, and need to rapidly estimate the distance to each fish, in order to decide whether it is inside the sampling unit. Harvey (1998) demonstrated that the magnitude of error for estimates of distance made by experienced divers may potentially result in an 82% underestimate, or 194% overestimate, of the actual area surveyed in UVC, and could greatly affect the density estimates for target species. This error was substantially reduced by use of a stereo-video system (mean relative error = –0.9%, SD = 2.6%), where targets outside a specified sampling area can be objectively identified in video interrogation using VMS. This could also allow the distances and sighting angles required by original line-transect theory (*sensu* Burnham *et al*. 1980) to be accurately measured and applied in line-transect estimations of fish density.

This objective identification of targets inside sampling transects was used by Harman *et al*. (2003), who used a swimmable stereo-video system to estimate the densities of 50 species of fishes associated with algal reefs in south-western Australia. Like normal UVC, those surveys overlooked very small and cryptic species, but did include the major mobile and sedentary reef fish families present. This video technique allowed detection of significant differences in fish abundance in all the treatments explored – bedrock type, topography and algal community composition. Given the success of Harman *et al.* (2003) in obtaining density estimates, there is obvious potential to raise stereo-video estimates of densities and length compositions with length–weight curves to overall biomass of reef fish communities.

Controlled assessments of swimmable video techniques using 3-chip, progressive-scan cameras in comparison with normal UVC are urgently needed to test the utility and biases of such video systems to estimate diversity and density of fishes along transects. Although it may be argued that the deployment of a swimmable system, requiring a camera separation of 1.0–1.5 m depending on transect dimensions, may make the presence of a dive team even more intrusive, there is clearly some potential to remove the need for divers skilled in both fish identification and estimation of fish length and transect dimensions. Only careful comparisons and calibrations with other techniques, similar to the long history of research on UVC, will allow the true potential of such complementary video techniques to be identified (e.g. Francour *et al*. 1999).

Even if these tests prove that skilled observers cannot be wholly replaced in UVC, the miniaturisation occurring now in camera systems provides the potential for the specialist diver to combine opportunistic video measurements with routine census of diversity and numbers along transects. Camera housings are now one-fifth of the size of the units originally employed by Harvey and Shortis (1998). Combined with an underwater navigation capability (for example using GPS on an underwater computer), such video measurement tools would allow the number, size and precise location of reef fish to be mapped in "roving swims" (*sensu* Newman *et al.* 1997), which are effective in finding rarer fish such as very large wrasses, carangids and serranids.

REMOTE VIDEO TOOLS IN DEEPER WATERS

Below the depth limits and beyond time limits of codes of scientific diving practice, video techniques offer great potential to record the community composition, relative abundance and size of fish without most of the "gear selection" inherent in extractive fishing techniques. Video sampling is non-extractive and, unlike research trawling, does not affect the seabed, so it allows information on protected species and "charismatic megafauna" (such as very large fish, including sharks and rays) to be repeatedly gathered in an acceptable manner in the widest range of marine park protection zones. Unlike normal fishing techniques, video also gives a detailed image of the habitat types in the sampling area.

With adequate lighting and housing materials, and control over timing of image acquisition, video techniques can be used for long durations at any time of day and potentially any depth. Three main approaches have been used: a remote camera system (the Aberdeen University Deep Ocean Submersible "AUDOS") deployed in abyssal depths (Priede *et al*. 1994); a live-feed, television camera system tethered by an umbilical cable to an anchored boat (the "BUV" of Willis and Babcock 2000); and single or replicate remote camera systems deployed with float ropes (Ellis and DeMartini 1995; Hill and Wassenberg 2000). Whilst Priede and Merrett (1996) and Willis and Babcock (2000) have sequentially deployed a single baited underwater video at small scales, our ongoing studies are simultaneously deploying fleets of 3–10 stations with or without bait, with or without stratification by habitat and depth, in studies of seafloor fish biodiversity at large scales.

Two major advantages of this approach are an ability to greatly increase sampling replication and sampling area, and to attract fish from potentially large areas by use of bait (see section below). These advantages can be used to reduce "zero counts" in surveys of deeper waters – to raise sample means, reduce coefficients of variation and thereby increase "sampling power" (Peterman 1990). For example, previous trapping surveys in the GBRMP had many "false negatives" caused by gear selectivity and other factors (see Cappo and Brown 1996 for review), and Williams et al. (1997) found that there was a significant linear correlation between the mean of a trapping sample and its standard deviation.

The fleet of single baited, remote underwater video stations, or "BRUVS" (Australian Institute of Marine Science), were designed for deployment on the rugose topography of deep coral reefs, and inter-reef shoals and soft substrata. The cameras lie 20 cm above the seabed with small scale-bars on the bait arm to allow for coarse measurements of fish in close proximity to them. The baited stereo-video pairs (University of Western Australia) are raised in a trestle-like frame 80 cm above the seabed, to allow unobstructed observations and precise measurements of demersal and pelagic fishes in heavily vegetated habitats of high latitudes, such as dense *Posidonia* seagrass beds and thick *Ecklonia* stands. Both sampling gears use cheaper single-chip digital "HandiCams" (Sony™ TRV18E MiniDV) in simple housings made from PVC pipe and acrylic sheet. They are deployed and retrieved with buoy ropes like traps and were developed for use on any seabed topography to provide a "hybrid" of the logistical advantages offered by UVC and baited fish traps, whilst avoiding some of the selectivity associated with both these methods. Unlike previous studies, we record all species identifiable in wide and deep vistas with independent, un-tethered cameras set in a horizontal plane, although the stereo-pairs allow definition of a specified field of view, outside which fish are not included in counts and measurements. Measurement protocols for both these systems were outlined in detail by Harvey *et al.* (2002b).

The diversity of species of fishes recorded has been exceptional: 228 in the deep lagoon at Scott Reef off north-western Australia (14°S), 194 in the inter-reef lagoon and shoals of the Central GBRMP (18°S), 74 in a pilot study of the urchin barrens and kelp reefs of the Solitary Islands of northern New South Wales (30°S), and 98 in the seagrass, bare sand, deep rhodolith beds and reefs, and kelp reef habitats of the Recherche Archipelago of south-western Australia (34°S). These included 50 mm monacanthids to 3 m sharks and rays. Set times ranged from 30 to 90 min, and the basic times of first arrival, time of first feeding, maximum number sighted in any one frame or period (*MaxN)*, time of *MaxN* and other parameters have been recorded at the level of the entire tape, or in 1 min intervals, although the permanent record allows us to revisit the footage and break it up for analysis in any time increments like the studies reviewed above.

A theme of our applications across latitudes has been to characterise the associations between mobile fishes and biotic habitats at scales useful to management. Notable taxa that separate the habitats have included herbivores (scarids, kyphosids, girellids and odacids), corallivores (chaetodontids, pomacanthids) and planktivores, as well as the expected carnivores and scavengers (eg carcharhinids, mustelids, labrids, lutjanids, nemipterids, lethrinids) and generalists (monacanthids, balistids). Many of the species sighted are notoriously shy of divers (e.g. gummy sharks *Mustelus antarcticus*, snapper *Pagrus auratus*), or not previously photographed underwater (e.g. southern sawshark *Pristiophorus cirratus*). Some of these groups, notably the sharks and carangids, have had little attention in the reef-fish literature.

ESTIMATING RELATIVE ABUNDANCE OF FISH BY USE OF BAITED VIDEO STATIONS

Baited videos record species attracted to the bait plume or camera station, species attracted to the commotion caused by feeding and aggregation at the station, species occupying territories within the field of view of the camera, and species indifferent to the station but present in or passing through the field of view during the deployment. The time of first arrival of a given species, the duration of its visit(s), the number present in the field of view in sequential time intervals, and the maximum number sighted in any one field of view (hereafter referred to as *MaxN*), and time of persistence of baits, are all readily available from time-coded video records. These parameters have been the focus of various models to estimate absolute density (individuals per area of sea floor) of abyssal scavenger fish (see Sainte-Marie and Hargrave 1987; Priede and Merrett 1996 for review) and relative density of predatory fishes (e.g. Ellis and DeMartini 1995; Willis and Babcock 2000; Yau *et al*. 2001).

The n_{peak} of Priede *et al*. (1994), the *MAXNO* of Ellis and DeMartini (1995), the *MAX* of Willis and Babcock (2000) and the *MaxN* of our studies are all homologous. This statistic under-estimates the true abundance of visiting fish in the bait plume. The occurrence of separate visits by different individuals of the same species is recorded as *MaxN*=1, and only a portion of a partially visible fish school contributes to *MaxN*. This usage implies more conservative estimates of abundance in high-density areas, and therefore differences detected between areas of high and low abundance (e.g. inside and outside reserves) are also likely to be more conservative.

Both Priede and Merrett (1996) and Willis and Babcock (2000) used a camera pointing downwards onto a fixed field of view on the seabed. Ellis and DeMartini (1995), Hill and Wassenberg (2000), and our studies use cameras lying on or parallel to the seabed, with no fixed depth of field – although this can be measured with stereo-video. The approaches and conclusions regarding abundance indices diverge further, with the studies of deepwater species in sets >11 h accounting for plume area of attraction in models (Sainte-Marie and Hargrave 1987; Priede and Merrett 1996; Yau *et al*. 2001), and the studies of shallower predators ignoring plume dispersal and using various calibrations of abundance indices during short sets (10–90 min).

The major disagreement of these studies concerns the value of *MaxN* as an indicator of abundance. Priede and Merrett (1996) have argued that the number of fish visible is the result of an equilibrium between arrivals and departures, and the "staying time" or "giving up time" is governed by Charnov's marginal value theorem of optimal foraging. This states that the staying time of an animal at an exhaustible food source is inversely related to the probability of finding an alternative food source. Thus, Priede *et al*. (1994) found the n_{peak} of abyssal grenadiers was higher (>10) at an oligotrophic location with low fish population and low food abundance because individuals stayed longer at the bait; in contrast, in a food-rich area with high population density the arrival rate was high because of the higher population, but n_{peak} was low (<5) because individuals gave up and left within an hour.

Ellis and De Martini (1995) used two baited video units with 10 min set times and recorded *MaxN* as the maximum number seen in a one-second interval (*MAXNO*), the time of arrival (*TFAP*), and a total duration of visit during a sequence (*TOTTM*). Their best video indices of relative abundance were calculated as means to standardise for multiple deployments per station. They found that *MAXNO* for the opakapaka (sharp-tooth snapper) *Pristipomoides filamentosus* and puffers *Torquigener florealis* was highly correlated with the total duration on film and time to first appearance of the respective species. They also found a correlation between *MAXNO* and long-line catch rates, and concluded that baited-video studies on shallow, productive grounds with short soak times could not be compared directly with the work on scavengers in abyssal waters with very long sets. *MAXNO* and *TFAP* were highly correlated, suggesting that the greater the snapper and puffer density, the faster the fish arrived at the bait. They estimated that only 18 sets of baited video would allow detection of a two-fold change in sharp-tooth snapper abundance.

Willis and Babcock (2000) and Willis *et al*. (2000) compared the MAX_n from baited underwater video (BUV) with UVC and angling, and also found that this index was correlated with fish abundance. They suggested that the lack of continuous monitoring in the various abyssal studies over very long sets resulted in potentially important losses of information as fish moved in and out of view. The focus of their studies, inside and outside a marine reserve, were snapper *Pagrus auratus* and blue cod *Parapercis colias*. During a 30 min BUV deployment, the number of each species at the bait in 30 s intervals was recorded to derive the MAX_{sna} and MAX_{cod} present in a sequence, together with the time at which these maxima were recorded (t_{MAXsna}), the time of first arrival of each species (t_{1stsna}), and the persistence of the external bait (t_{BG}). They demonstrated BUV to be an effective and sometimes superior alternative to UVC. MAX_n was the best index, but of the time-based indices t_{1stcod} was best, because it appeared that blue cod responded to bait so well that speed of arrival did reflect abundance. Statistically significant differences between reserve and non-reserve were detected after only 5 min set time, and became more significant with increasing time of deployment of the BUV.

Although indices of relative abundance are available from baited, stationary video techniques, the area of influence of the bait plume must be accounted for in order to estimate sampling areas and convert the indices to density estimates. Studies of abyssal and deep-sea fishes have sought to use *MaxN* and arrival time, in conjunction with knowledge of current velocities, fish swimming speeds and models of bait-plume behaviour, to derive absolute density estimates. Sainte-Marie and Hargrave (1987) used patterns of arrival, times of first arrival on bait, and instantaneous numbers of animals on bait to estimate abundance and distance of attraction for scavenging fish and invertebrates. They used a simple Gaussian model to account for the rate of odour production by bait, chemosensory thresholds of scavengers, swimming speed of scavengers relative to current velocity, and satiation time ("staying time" of Priede *et al*. 1994). They listed six major working assumptions and data requirements, concerning current velocities and swimming speeds, behaviour and distribution of the scavengers, the rate of bait-odour release and chemosensory thresholds of the animals. They could then estimate abundance from the curve of cumulative arrivals and from the arrival times of the first individual on bait.

Priede *et al*. (1990) developed the AUDOS to estimate abyssal fish densities; it was a free-fall, pop-up instrument package that carried a camera system, a current meter, scanning sonar and electronic compass. It was suspended in a mooring, with the downward-looking camera suspended 1.43 m above bait tied to ballast resting on the seafloor. Photographs of a 3–6 m^2 field of view containing a standard bait were usually taken at 1 min intervals for 13 h or more. The maximum number within frame within 15 min increments was used as n_{peak}, since this was presumed to overcome the problem of fish entering and leaving the field of view.

They proposed that, in a plot of number of fish at time t (N_t) against the soak time (t min), an initial fish arrival rate is relatively rapid, rising to a peak (n_{peak}) and declining as fish depart. A curve fitted to the data cloud could then be broken up into a steeper arrival curve and a shallower departure curve, which are identical in shape but are separated by a time that corresponds to the mean "staying time" of fish. The difference between the two curves was used to give the actual number present in the subsequent AUDOS studies.

Estimation of the distance from which the first fish was attracted to the bait from the current velocity and fish swimming speed has also formed the basis for Priede's estimates of relative abundance. However, Yau *et al*. (2001) noted for Patagonian toothfish, and other shallow-water fishes, that the inverse relationship between abundance and the square of the average arrival time in Priede's model will cause problems, because small changes in arrival times cause major changes in theoretical density estimates. Shallow-water sets usually produce visitors very quickly and can also produce far larger numbers of fish in the field of view than the abyssal deployments.

Our studies in both low and high latitudes have shown that, although only a small percentage of visitors actually feed at the bait, the effect of the bait plume is to bring in more species – not just from a few carnivorous or scavenging functional groups, but also from herbivorous, corallivorous and most other mobile functional groups. Unpublished species-accumulation curves for baited ($N_{species} = 27.5 \ln(N_{sets}) + 20.39$) and unbaited ($N_{species} = 6.59 \ln(N_{sets}) + 1.26$) video sets in the GBRMP showed that, on average, baited videos recorded 5 times more species in the first two deployments than unbaited stations. The curves showed no evidence of convergence, indicating that increasing replication of unbaited sets would not approach the efficiency of baited sets. A similar phenomenon was evident in several high-latitude habitat types in the Recherche Archipelago.

The only ways to discern the biases of the baited video technique are to compare it with UVC and common extractive techniques, such as trawling and trapping. In this regard, Cappo *et al*. (in press) found that a prawn trawl and BRUVS recorded significantly different components of the fish fauna on soft-bottom inter-reef habitats. Trawls caught mainly small , sedentary or cryptic, demersal species – such as flatfishes, apogonids, saurids, triglids and callionymids. The BRUVS recorded more larger, mobile species from a much wider size range of families, including large elasmobranchs, more pelagic species (such as carangids and scombrids), and numerous eels. The BRUVS performed best in the day, and trawls caught more species at night. Multivariate analyses showed that both techniques indicated the presence of very similar patterns of grouping of fish species assemblages, despite sampling quite different components of the fauna. Six fish assemblages were recognized, based on day and night in three sampling locations.

In summary, there are three major challenges in exploring the potential for stationary video techniques to estimate relative abundances of fish and convert them to density estimates: separating repeated visits of the same fish from new arrivals within video tapes to get a better *MaxN* and more accurate measurements of length-frequency compositions of visitors; estimating the sampling area; and, addressing the notion that *MaxN* is related more to the prevailing feeding opportunities in a habitat than to fish abundance. These topics will require calibrations with other sampling techniques, better, ground-truthed models of bait-plume dynamics, and closer attention to the species replacements and dynamics of fish visits and interactions within single tapes.

CONCLUSIONS

Survey methods for the initial exploration and later monitoring of Marine Protected Areas must accommodate wide variability in the behaviour and habitat requirements of numerous fish groups, and newly emerging video techniques can play an increasing role. Swimmable, stereo-video systems could enhance the performance of unskilled (and skilled) SCUBA observers by postponing subjective, difficult tasks of estimating fish identities, numbers, lengths and positions underwater, to objective interrogations of tapes at leisure in the laboratory for an unlimited audience. Integration of the geostationary positioning capacity of underwater computers with digital stereo cameras swum by divers along transects, or in roving swims, could allow accurate mapping of the position, length and biomass of important fish species in a geographic information system. Non-extractive, remote video sampling stations can be operated in low-visibility conditions, independent of depth or seabed rugosity, with fewer staff. They provide information on the immediate habitat in the sampling area, and are less prone to return low (or zero) abundance estimates for a range of species – implying that statistical power of comparisons of relative abundance is likely to be greater, with lower field costs, than some types of fishing techniques. They are biased by the use of bait, but they may avoid many of the problems with size-selectivity of capture gear, variable vulnerability to capture, and inter- and intra-specific competition for hooks or trap ingress. The disadvantages are related mostly to the uncertainty surrounding the best estimator of fish numbers within tapes, and the actual area sampled, to estimate relative and absolute abundance. The interrogation time needed to analyse tapes broken up into time increments is also a "bottleneck" in application of the technique. Although length measurements obtained by stereo-video are now known to be better than those provided by divers, field tests and calibrations with other techniques are urgently required to fully appraise the potential of the swimmable and stationary video techniques to estimate fish densities.

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USE OF SURROGATES FOR THE RAPID ASSESSMENT OF MARINE BIODIVERSITY

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Abstract

Selection of sites for marine conservation is often based on biological surveys that aim to assess biodiversity of candidate areas. Measuring to species diversity level is slow and expensive. One way of reducing costs is to use surrogates, sometimes called indicators, to assess biodiversity. The effectiveness of two surrogates – habitats (e.g. limestone, granite reef) and higher taxonomic levels (e.g. genus, family, Order) – was tested on data from three marine biological surveys in temperate south-western Australia. Results indicated that habitat information such as geographic region, substratum, reef relief and depth could be used to distinguish different patterns in species diversity, because significant differences were found in species composition from different habitat types. Higher taxonomic levels (genus, family) were effective for predicting patterns in species diversity. At these taxonomic levels, most patterns in species diversity were retained. Order level was an unreliable surrogate, because many patterns in species diversity were not maintained at this level, especially for fish assemblages. The outcomes described here are specific to those taxa and habitats of temperate south-western Australia. Any generalization created from these specific results would require further testing in other regions.

Keywords: marine surveys, biodiversity, surrogates, habitat

INTRODUCTION

The creation of Marine Protected Areas (MPAs) has been recognised as an important tool for conservation and fisheries management (Roberts and Hawkins 2000; Ward *et al.* 2000). In Australia, the National Representative System of Marine Protected Areas (NRSMPA) is being established to expand the existing system of marine parks and reserves, with the aim being "to protect areas which represent all major ecological regions and the communities of plants and animals they contain". Part of the implementation of this government initiative in Western Australia (WA) was a report by the Marine Parks and Reserves Selection Working Group (1994), which aimed to identify areas of WA having particular values for conservation, science and public recreation, making them worthy of inclusion in a representative marine reserve system. The introduction of MPAs is a fairly recent phenomenon compared with terrestrial reserves, and the selection of marine areas for protection has so far been a largely *ad hoc* process, depending more on social criteria and opportunism than on scientific study (McNeill 1994; Roberts 2000).

To improve this situation and maximise the chances of achieving the objectives of the NRSMPA, a rigorous scientific approach is needed to optimise reserve selection and design (Roberts 2000). There is an urgent need to document distributions of marine biodiversity. Biodiversity is complex, and encompasses genetic diversity (the variation of genes within a species), species diversity (the variety of species within a region), assemblage diversity (the variety of assemblages of species within a region) and diversity of ecosystems (the variety of ecosystems within a region) (Anon. 1995; Ward *et al.* 1997). Obtaining full knowledge of marine biodiversity is impossible even to the level of total species diversity. Time and costs involved with exhaustive surveys prevent this kind of inventory from taking place (Williams and Gaston 1994). The magnitude of this task has therefore forced ecologists to consider indirect methods for sampling species diversity (Roy *et al.* 1996).

In this sense, one way of assessing species diversity more rapidly is by the use of surrogates. Surrogates are used to represent, or substitute for, species diversity, and are more easily measured or more readily available than species diversity (Ward *et al.* 1997). Effective surrogates rely on the empirical establishment of a relationship between diversity and the surrogate (Gaston 1996; Vanderklift and Ward 2000). To improve our knowledge of national marine biological diversity we must agree on a set of effective surrogates for biodiversity, to be used in the planning and management of biodiversity. This has led to our testing of two types of surrogates against species diversity in areas under consideration for MPAs.

The first hypothesis of this study is: information on habitat can predict patterns in species diversity on temperate reefs in WA. The main advantage of using habitat types as a surrogate for species diversity is that data on habitats are usually more widely available, in spatially explicit formats (GIS), or are easier to obtain than biological data (Ward *et al.* 1997). Though habitat is a multiple-variable descriptor of the environment in which organisms occur, we use four descriptors to summarise habitat: substratum, reef relief, depth and exposure to swells. Various studies have found algal species diversity to be influenced by each of these habitat factors (Harlin and Lindbergh 1977; Schiel and Foster 1986; Wells *et al.* 1989; Underwood and Kennelly 1990; Underwood *et al.* 1991; Davidson and Chadderton 1994; Phillips *et al.* 1997; Kendrick *et al.* 1999a). Substratum, relief, depth and exposure also are related to patterns in fish species diversity (Luckhurst and Luckhurst 1978; Bell 1983; Putt *et al.* 1986; Jones and Andrew 1990; Carr 1991; McCormick 1994; Parker *et al.* 1994; Jennings *et al.* 1996; Chapman and Kramer 1999; Connell and Lincoln-Smith 1999; Hyndes *et al.* 1999; Yoklavich *et al.* 2000). Differences in sponge communities between different habitats, including different depths and degrees of exposure, have also been recorded (Underwood *et al.* 1991; Underwood and Kennelly 1990; Wright *et al.* 1997).

The second hypothesis is: higher taxonomic levels can predict patterns in species diversity on temperate reefs in WA. The advantage of this surrogate is that by measuring diversity at higher taxonomic levels, survey costs should be greatly reduced, because identification to species level would be unnecessary (Williams and Gaston 1994). Family richness has been found to be a good predictor of species richness for a variety of terrestrial taxa (Williams and Gaston 1994). In the marine realm, diversity patterns at the genus and family levels were significantly correlated with those at species level for eastern Pacific marine molluscs (Roy *et al.* 1996). Data on nematode and marine macrofaunal communities have shown retention of overall patterns of community structure at higher taxonomic levels (Somerfield and Clarke 1995). Vanderklift *et al.* (1998) found that genus assemblages resulted in the selection of areas with a similar number of species to those obtained by using species assemblages, but results using family and class assemblages varied and were inconclusive.

METHODS

Study design and data collection

We addressed the hypotheses stated above using data collected on species composition of algae, fish and sponges from two recent broad-scale biological surveys conducted in south-western Australia (Fig. 1).

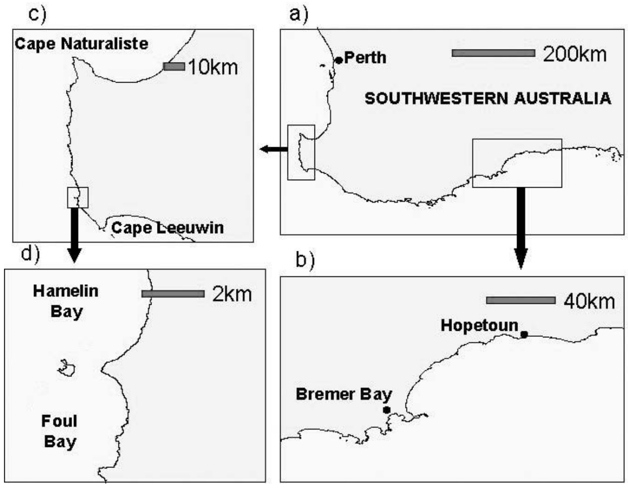

Fig. 1. Survey locations (*a*) South-western Australia, (*b*) extent of the 1997 South Coast survey, (*c*) extent of the 1999 Capes survey, (*d*) area of the 2001 Hamelin Bay survey.

The data were used to find trends that infer that habitat or higher taxonomic levels could be used as a surrogate for species diversity. A small-scale survey at Hamelin Bay then attempted to validate the hypotheses generated from the broader-scale surveys. The determination of the effectiveness of higher taxonomic levels as a surrogate for species diversity was partly reliant on the establishment of patterns in species diversity (see Fig. 2 for flowchart used to test hypotheses).

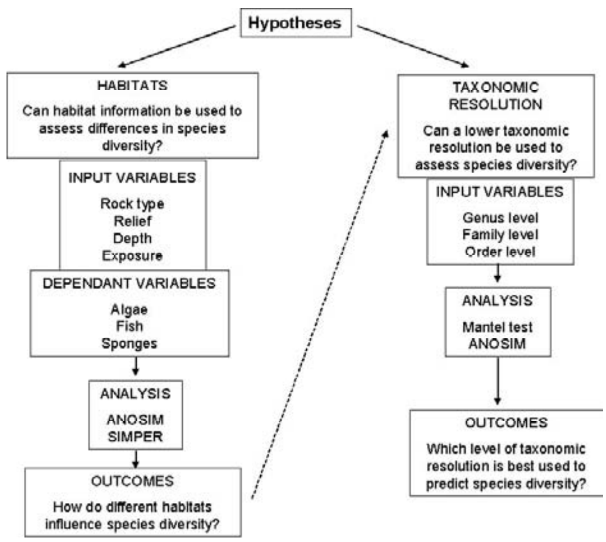

Fig. 2. Flowchart used to test hypotheses.

The first dataset (hereafter referred to as the South Coast survey) was obtained from a biological survey conducted in March 1997 and 1998, by the Department of Conservation and Land Management (CALM) and the University of Western Australia (UWA), of a region on the south coast of WA, from Starvation Boat Harbour to Groper Bluff (Fig. 1b). The second dataset (hereafter referred to as the Capes survey) was obtained from another biological survey conducted by CALM, UWA and Murdoch University, in February 1999, in the Geographe Bay–Capes–Hardy Inlet region (Fig. 1c). The third data set was obtained in the Hamelin Bay region (Fig. 1d) in February 2001. Hamelin Bay is within the area covered by the Capes (1999) survey and is used to test the hypotheses generated from that survey.

Survey techniques: South Coast (1997)

During the South Coast survey, a 200 m transect line was laid down at each of 39 sites. Fish species were surveyed by visual estimation, with SCUBA divers counting large fish on 5 m either side of the transect line. Smaller and more cryptic fish species were surveyed in 1m along one side of the transect. At 5 m intervals along the transect the percentage cover of sponges was recorded in a 1 m^2 quadrat. Macroalgae were sampled at 20 m intervals along the transect line in a 0.25 m^2 quadrat (Colman 1997). Habitat variables recorded at each site included four substratum types (seagrass meadow, limestone reef, granite reef and schist/quartzite reef); and various maximum depths <17 m. For more detail on this survey see Colman (1997).

Survey techniques: Capes (1999)

The Capes survey incorporated sites of different geographical regions (southern/western shores exposed to dominant wind/swell direction and northern shores sheltered), two substratum types (limestone reef and granite reef), two reef aspects (high and low relief), and a variety of depths <26 m. The survey incorporated 20 sites. Macroalgae were collected by harvesting from six randomly placed 0.25 m^2 quadrats at each site and identified to species. Sponges were sampled from six different quadrats at each site. In many cases, however, sponges were only tentatively identified to family level. Reef fish were assessed by visual estimation, where SCUBA divers counted fish along twelve 25 m transects (5 m wide for large fish, and 2 m wide for more cryptic fish) at each site. For further details on this survey see Kendrick *et al.* (1999b).

Survey techniques: Hamelin Bay (2001)

To achieve the aims of this part of the study, sites were chosen to test hypotheses about differences in fish and algal assemblages among different habitats. Nine sites, all approximately 10 m in depth, were sampled to test specifically for differences between substratum types (limestone and granite) and degrees of vertical relief (>2m, high relief; <2m, low relief). On the Capes (1999) Survey, labelling of sites as either high or low relief was imprecise when the area was not consistently one or the other. Consequently, the Hamelin Bay survey was designed so that sites were chosen on the basis that a site was consistently either high or low relief, and was large enough to survey. The Hamelin Bay survey used an underwater stereo-video technique to survey reef fish (Harvey and Shortis 1996), to eliminate many of the observer-bias problems associated with visual estimation -(Harvey *et al.* 2001a, b, 2002) that were experienced in the 1997 South Coast and 1999 Capes surveys (see Kendrick *et al.* 1999b). At each site, twelve 25 m transects were swum on three separate occasions (to account for short-term temporal variation). These transects were swum by two SCUBA divers with two video cameras mounted on a stereo-video frame and encased in underwater housing (Harvey and Shortis 1996; Harvey *et al.* 2002). Algae were harvested from six randomly placed 0.25 m^2 quadrats at each site, sorted to species level and wet weighed. Sponges and their taxonomy were not detailed enough for confidence, and consequently these were excluded from the Hamelin Bay survey.

Data analysis

ANOSIM (Analysis of Similarities) tests were conducted to determine significance for dissimilarity between different habitats. These were based on the creation of association matrices using the Bray–Curtis coefficient (Bray and Curtis 1957) with either no transformation (for data in presence/absence format) or with a presence/absence transformation (for abundance data). If ANOSIM tests determined two groups of samples to be significantly different, the SIMPER (Similarity Percentages) routine was used to identify species most responsible for this difference. The top five contributing species were listed in decreasing order of their importance in discriminating between two groups. To assess how much patterns in diversity change at progressively higher taxonomic levels, species-based association matrices were compared with those based on data pooled at the genus, family or Order level by the Mantel test (Belbin 1995).

RESULTS

Habitat information can predict patterns in species diversity on temperate reefs in Western Australia

South coast survey (1997)

In general, the macroalgae assemblages of different substrata were significantly different (Table 1). Specifically, limestone and granite reefs were the two substrata that were significantly different in terms of macroalgae species composition (Table 2). All five algae species identified by SIMPER as most responsible for the difference between the two substrata were more common on limestone reefs than granite reefs (Table 3a). Significant differences in fish species composition were also found among substrata (Table 1). When the pairwise tests were examined, specific differences existed between limestone and schist/quartzite reefs, limestone and granite reefs, and granite reefs and seagrass (Table 2). The strongest contributors to significant differences between substrata were fish, which favour schist/quartzite reefs and/or granite reefs instead of limestone reefs (Table 4a,b). The top five fish contributing to the difference between seagrass and granite were all fish favouring granite over seagrass (Table 4c). Sponges also differed between substrata (Table 1). Specifically, pairwise tests indicated that seagrass and granite were significantly different (Table 2). The sponge species with the five top contributions to the difference between seagrass and granite were mainly sponges more common on granite, except

Table 1. South Coast and Capes species-based global ANOSIM results, for all habitat components and each assemblage, with Clarke's *R* and significant *p* values in bold.

Survey	Habitat Components	Assemblage	R	*p*
South Coast	Substratum (granite, limestone, seagrass, schist/quartzite)	Algae	0.323	**0.01**
		Fish	0.462	**0.001**
		Sponges	0.215	**0.025**
	Depth (<5 m, 5—10 m, >10 m)	Algae	0.122	0.097
		Fish	0.043	0.257
		Sponges	–0.2	0.999
Capes	Geographical Region (north, west/south)	Algae	0.472	**0.003**
		Fish	0.074	0.244
		Sponges	–0.118	0.784
	Substratum (granite, limestone)	Algae	0.217	**0.042**
		Fish	–0.015	0.473
		Sponges	0.177	0.055
	Depth (<10m, 10-20m, >20m)	Algae	0.031	0.374
		Fish	–0.11	0.797
		Sponges	–0.026	0.57
	Relief (high, low)	Algae	–0.004	0.471
		Fish	0.025	0.28

Table 2. All significant species-based global/pairwise ANOSIM results for the South Coast and Capes analysed at four taxonomic levels, with Clarke's *R* and significant *p* values in bold.

Survey	Habitat components	Assemblage	Species		Genus		Family		Order	
			R	*p*	*R*	*p*	*R*	*p*	*R*	*p*
South Coast	limestone *v.* granite	Algae	0.518	**0.017**	0.436	**0.029**	0.494	**0.021**	0.327	**0.045**
		Fish	0.889	**0.002**	0.902	**0.001**	0.647	**0.005**	0.593	**0.014**
	limestone *v.* schist/quartzite	Fish	0.713	**0.018**	0.703	**0.018**	0.487	**0.036**	0.333	0.054
	seagrass *v.* granite	Fish	0.659	**0.001**	0.619	**0.001**	0.59	**0.001**	0.006	0.322
		Sponges	0.427	**0.003**	n/a	n/a	0.41	**0.003**	0.152	0.085
	<5 m *v.* >10 m	Algae	0.533	**0.018**	0.576	**0.023**	0.608	**0.014**	0.258	0.105
Capes	north *v.* west/south	Algae	0.472	**0.003**	0.429	**0.006**	0.406	**0.005**	0.547	**0.001**
	limestone *v.* granite	Algae	0.217	**0.042**	0.152	0.099	0.05	0.324	0.301	**0.017**
	<10 m *v.* >20 m	Algae	0.389	**0.033**	0.558	**0.017**	0.429	**0.025**	0.04	0.333

for *Oceanapia* sp. 2, which was absent from granite but present in seagrass (Table 5).

No significant differences in algae were found between various depth groups when analysed together (Table 1). There was a significant difference, however, in algae species between sites <5m deep and sites >10m deep (Table 2). Strong contributors to the difference between shallow and deep areas, as indicated by SIMPER, were the large brown algae, *Sargassum* spp. and *Ecklonia radiata*, which were more representative of deeper areas (Table 3b). Two species of smaller red algae, *Osmundaria prolifera* and an unidentified filamentous red alga, as well as the brown alga *Scaberia agardhii*, were more common in shallow areas (Table 3b). There were no differences associated with depth for either fish species or sponge taxa (Table 1).

Table 3. Algae species SIMPER results, showing the top five species in terms of contributions to dissimilarity and average relative abundances based on presence/absence data.

Reference	Survey	Species	Habitat (average relative abundances)	
			Limestone	**Granite**
(a)	South Coast	*Caulocystis uvifera*	1	0
		Scaberia agardhii	1	0.19
		Osmundaria prolifera	1	0.25
		Laurencia sp.	1	0.31
		Filamentous red alga	0.67	0
			<5m	**>10m**
(b)	South Coast	*Sargassum* spp.	0	1
		Osmundaria prolifera	1	0.22
		Scaberia agardhii	0.67	0
		Ecklonia radiata	0.33	1
		Filamentous red alga	0.67	0
			West/South	**North**
(c)	Capes	*Sargassum* spp.	0.07	1
		Ecklonia radiata	0.87	0.2
		Laurencia sp.	0.13	0.8
		Callophyllus sp.	0.67	0
		Peyssonnelia rubra	0.73	0.2
			Limestone	**Granite**
(d)	Capes	*Curdiea obesa*	0.83	0.21
		Pterocladia lucida	0.83	0.21
		Erythrymenia minuta	0.67	0.14
		Pterocladia sp.	0.67	0.14
		Callophyllus sp.	0.83	0.36
			<10m	**>20m**
(e)	Capes	*Hypoglossum* sp.	0.08	1
		Metagoniolithon radiatum	0.83	0
		Curdiea obesa	0.58	0
		Plocamium preissianum	0.17	0.67
		Platythalia angustifolia	0.58	0
			Limestone	**Granite**
(f)	Hamelin Bay	*Platythalia angustifolia*	0.06	0.82
		Zonaria sp.	0	0.64
		Phacelocarpus apodus	0	0.64
		Ecklonia radiata	0.78	0.36
		Nizymenia conferta	0	0.45
			Low Relief	**High Relief**
(g)	Hamelin Bay	*Scytothalia doryocarpa*	0.78	0.28
		Amphiroa anceps	0.22	0.72
		Ecklonia radiata	0.78	0.5
		Pterocladia lucida	0.33	0.56
		Metagoniolithon radiatum	0.17	0.5

Table 4. Fish species SIMPER results, showing the top five species in terms of contributions to dissimilarity and average relative abundances based on presence/absence data.

Reference	Survey	Species	Habitat (average relative abundances)	
			Limestone	**Schist/Quartzite**
(a)	South Coast	*Siphonognathus beddomei*	0	0.8
		Achoerodus gouldii	0	0.8
		Dotalabrus alleni	0	0.8
		Enoplosus armatus	0	0.8
		Pseudolabrus biserialis	0.33	1
			Limestone	**Granite**
(b)	South Coast	*Siphonognathus beddomei*	0	0.88
		Achoerodus gouldii	0	0.88
		Kyphosus sydneyanus	0	0.81
		Pempheris multiradiata	0	0.75
		Pseudolabrus biserialis	0.33	1
			Seagrass	**Granite**
c)	South Coast	*Scorpis aequipinnis*	0.14	1
		Parma mccullochi	0	0.88
		Pseudolabrus biserialis	0.21	1
		Achoerodus gouldii	0.07	0.88
		Nemadactylus valenciennes	0.07	0.88
			Limestone	**Granite**
(d)	Hamelin Bay	*Odax cyanomelas*	1	0.22
		Pempheris klunzingeri	0.78	0.11
		Coris auricularis	0.67	0.78
		Dactylophora nigricans	0	0.44
		Parma mccullochi	0.67	1
			Low Relief	**High Relief**
(e)	Hamelin Bay	*Pempheris multiradiata*	0	0.78
		Kyphosus sydneyanus	0.33	1
		Chelmonops truncatus	0.11	0.78
		Scorpis aequipinnis	0	0.67
		Notalabrus parilus	0	0.67

Table 5. Sponge taxa SIMPER results, showing the top five species in terms of contributions to dissimilarity and average relative abundances based on presence/absence data.

Survey	Species	Habitat (average relative abundances)	
		Seagrass	**Granite**
South Coast	*Microcionidae* sp. 2	0.29	0.9
	Antho sp. 1	0.14	0.6
	Echinoclathria sp. 1	0.14	0.5
	Oceanapia sp. 2	0.43	0
	Calcarea sp. 1	0.14	0.6

Table 6. Hamelin Bay global ANOSIM results analysed at four taxonomic levels, with Clarke's *R* and significant *p* values in bold.

Survey	Habitat Components	Assemblage	Species		Genus		Family		Order	
			R	*p*	*R*	*p*	*R*	*p*	*R*	*p*
Hamelin Bay	limestone *v.* granite	Algae	0.586	**0.001**	0.59	**0.001**	0.578	**0.001**	0.495	**0.001**
		Fish	0.507	**0.001**	0.511	**0.001**	0.466	**0.001**	0.028	0.198
	high *v.* low relief	Algae	0.347	**0.001**	0.385	**0.001**	0.407	**0.001**	0.323	**0.001**
		Fish	0.658	**0.001**	0.581	**0.001**	0.488	**0.001**	0.059	0.144

Capes survey (1999)

Algae species found in the northern, more sheltered area of the Capes region were significantly different to those of the more exposed southern and western-facing coasts (Table 1). *Sargassum* species contributed the most to dissimilarity between west/south sites and northern sites, being more prevalent in the northern sites, whereas the kelp *Ecklonia radiata* was more common on the western and southern coasts (Table 3c). Neither fish nor sponges showed any significant differences related to geographical region (Table 1).

Differences among substratum types and depths were obtained by two-way crossed ANOSIMs for algae species. The composition of algae species was significantly different between granite and limestone when allowing for differences between depth groups (Table 1). All five species most responsible for the difference between limestone and granite reefs, including two *Pterocladia* species, were more common on limestone than granite (Table 3d). No differences were found between substratum types for fish or sponges (Table 1).

A significant difference in algae species between sites less than 10 m in depth and sites greater than 20 m (when differences among substratum types were taken into account) was also revealed by the two-way crossed ANOSIM test (Table 2). Algae species most responsible for differences between these depths (Table 3e) were *Hypoglossum* sp. and *Plocamium preissianum*, which were more characteristic of deeper areas, and *Metagoniolithon radiatum*, *Curdiea obesa* and *Platythalia angustifolia*, which were abundant in shallow areas, but absent from the deeper sites. Fish and sponges did not show significant differences related to depth (Table 1).

No differences in algae, fish or sponge species were found between sites of high and low relief (Table 1).

Establishment of hypothesis and structured testing

Results of these two broad-scale surveys confirm that different habitats support different assemblages in south-western Australia. The main factor influencing algae, fish and sponge assemblages was substratum. For macroalgae, depth and geographic region were also important. As the 1997 South Coast and 1999 Capes surveys were not designed for testing specific hypotheses, further empirical testing of habitat (as a surrogate for species diversity) was required. Both substratum type and relief were tested at shallow depths at Hamelin Bay.

Hamelin Bay Survey (2001)

There were significant differences between limestone and granite reefs, for both algae and fish species (Table 6).

The top five algae species responsible for the differences between limestone and granite reefs were *Platythalia angustifolia*, *Zonaria* sp., *Phacelocarpus apodus* and *Nizymenia conferta*, which were more abundant on granite reefs, while *Ecklonia radiata* was more abundant on limestone reefs (Table 3f). In terms of fish, limestone reefs were characterised by a greater number of *Odax cyanomelas* (herring cale) and *Pempheris klunzingeri* (rough bullseye), while *Coris auricularis* (western king wrasse), *Dactylophora nigricans* (dusky morwong), and *Parma mccullochi* (common scalyfin) were more abundant on granite reefs (Table 4d).

There were also significant differences in algae and fish assemblages between high-relief and low-relief reefs (Table 6). The macroalgae *Scytothalia doryocarpa* and *Ecklonia radiata* were more abundant on low-relief reefs, whereas *Amphiroa anceps*, *Pterocladia lucida,* and *Metagoniolithon radiatum* were more abundant on high-relief reefs (Table 3g). All five fish species with the greatest contributions to the dissimilarity between high- and low-relief limestone reefs were more abundant at high-relief rather than low-relief reefs (Table 4e). In summary, substratum type, depth and relief of reef are important habitat components for capturing differences in the composition of algae, fish and sponge assemblages in south-western Australia.

Higher taxonomic levels can predict patterns in species diversity on temperate reefs in Western Australia

South coast survey (1997) and Capes survey (1999)

Similarity matrices based on algae species were compared with similarity matrices based on algae genera, families and Orders by the Mantel test. The correlation between matrices decreased at increasingly higher taxonomic levels (Figs 3a, 3b), but the Capes data had a lower degree of correlation at each taxonomic rank than the South Coast data. The reason for these differences can be attributed to the number of species in each dataset, and the ratio of species to higher taxa. The Capes data included 161 algae species and the South Coast survey had 78 algae species. The ratio of the species to numbers of higher taxa differs in each data set (Table 7). These data had a higher species:genus ratio, species:family ratio and species:Order ratio than those of the South Coast data.

Table 7. Ratios of species to higher taxa for all assemblages and each survey.

Assemblage	Survey	Species:Genus	Species:Family	Species:Order
Algae	South Coast	1.625	2.69	4.875
	Capes	1.713	3.28	7
	Hamelin Bay	1.404	2.2	4.714
Fish	South Coast	1.257	2.37	8.3
	Capes	1.319	2.714	10.55
	Hamelin Bay	1.1628	1.724	8.333
Sponges	South Coast	n/a	2	3.636
	Capes	1.172	1.786	3.57

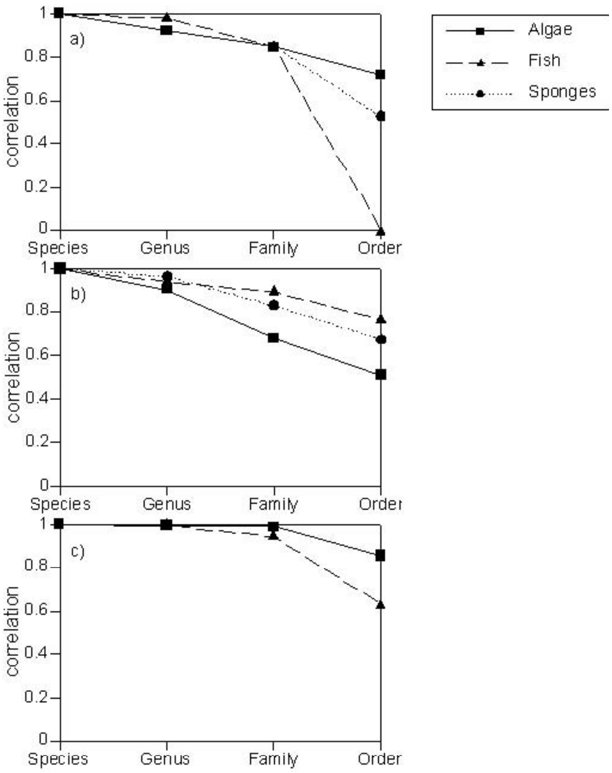

Fig. 3. Mantel-test correlations between species-based and higher-taxon-based similarity matrices for (*a*) the South Coast survey, (*b*) the Capes survey, (*c*) the Hamelin Bay survey.

Correlations between species and genus level patterns for fish were fairly strong (Figs 3a, 3b), and this was reflected in fairly low species:genus ratios for both datasets (Table 7). At the family level there was still a fairly high correlation of around 0.9 for both data sets (Figs 3a, 3b), but a marked drop in the level of correlation at the Order level for the South Coast data (Fig. 3a). As seen in Table 7, the species:Order ratio was very high in both datasets, with around 8 to 10 species per Order. The majority of the fish species are in one Order, the Perciformes.

In many cases, the sponges sampled in both the Capes and South Coast surveys were identified only to Order or to family, and there were some unidentified species, e.g. Spongiidae sp. 1. Without all the relevant taxonomic information, breaking the data down into four taxonomic datasets was difficult. In the case of the South Coast sponges, there would have been no difference between a species-level dataset and a genus dataset, therefore no genus data set was included. The ratios of sponge species to genera, families and Orders, as far as they could be differentiated, are shown on Table 7. A progressively lower correlation was found between species and higher taxonomic level similarity matrices, for sponges in both the South Coast and Capes regions (Figs 3a, 3b), suggesting that data were lost at a consistent rate when they were pooled to each higher taxonomic level.

In terms of retaining patterns in species diversity (as defined in Table 2) at the higher taxonomic levels of genus and family, most of the significant habitat-related patterns were maintained. The only pattern established for species that was not also evident at genus and family level was a significant difference for algae between limestone and granite reefs in the Capes survey (Table 2). When organisms were pooled at Order level, only four out of the nine established patterns remained significant (Table 2). Order-level surrogacy was better for algae than for fish, with three out of five patterns in species diversity maintained. For the habitat components substratum type and relief, the effect of higher taxonomic classifications was also tested at Hamelin Bay.

Hamelin Bay survey (2001)

For algae, correlations were very high between species-level matrices and both genus- and family-level matrices, but dropped considerably at Order level (Fig. 3c). The Hamelin Bay dataset comprised 66 species of algae, and ratios of species to higher taxa (Table 7) were relatively low.

Fish-data analysed at the genus and family levels also had strong correlations to patterns in fish species diversity and, again, there was a marked drop in correlation at the Order level (Fig. 3c). As with the two other surveys, there is a very high fish species:Order ratio (Table 7), because most of the fish belong to just one Order.

All significant habitat-related patterns in species diversity were retained when data were pooled at genus and family levels (Table 6). Algae Orders also produced significant patterns, but patterns were lost for fish Orders (Table 6).

DISCUSSION

Can habitat information predict patterns in species diversity on temperate reefs in Western Australia?

Habitat is a multi-variable term made up of geomorphological, bathymetric, oceanographical and biological factors. Along the south-western coast of Australia, it is possible to make generalisations in regard to habitat and its influence on species diversity. The relationships that exist between species diversity and habitat (geographic region, substratum, relief and depth) suggest habitat could potentially be used as a surrogate for species diversity. In a potential MPA network, ensuring maximum biological diversity would necessitate the inclusion of representative samples of each of these habitat components, as a minimum. When planning a MPA, surveying habitat components would reduce time and cost.

Though there is a differentiation in assemblages of organisms occurring in different habitats, each assemblage follows different trends. Patterns in algae, fish and sponge diversity were not consistent, indicating that the use of only one assemblage to represent all assemblages would not be successful. This main outcome differs from that of Gladstone (2002) for coastal New South Wales. A cost-effective alternative to a detailed fine-scale biodiversity survey would therefore be to conduct a broad-scale habitat survey along with a smaller biological survey of species diversity across the range of habitats.

A relationship between habitat type and species diversity has been shown for all surveys in south-western Australia. To what extent can we use different habitat types to represent different species assemblages? Gaston (1996) states that extrapolating surrogates outside the context within which a relationship has been developed is dangerous. A surrogate must only be used after being subjected to empirical tests of assumptions and only employed when those assumptions have been tested and found to hold. Habitats cannot be assumed to act as a surrogate for species diversity using habitat variables other than the ones tested in this study, or to represent assemblages other than the ones tested here. In a region outside south-western Australia, the use of this surrogate should be based on the establishment of an empirical relationship between habitat types and species diversity in that region.

In the implementation of marine reserve areas in south-western Australia, the recognition of habitat types as an effective surrogate for species diversity is only the first step. A decision is required as to how many specific representative examples of each habitat type should be included. Ward *et al.* (1999) compared percentage representation of different habitats in a marine reserve to the percentage of overall taxa that would then be included in the reserve. In WA, the next step in using habitat categories to represent species diversity should be to investigate how many examples of each habitat type would need to be represented in a reserve area in order to conserve maximum biological diversity in the region. Also, complementarity analysis for habitat factors may then prove an effective tool in calculating the actual minimum area that would then need to be placed in reserves for maximum conservation.

Can higher taxonomic levels predict patterns in species diversity on temperate reefs in Western Australia?

Both genus- and family-level data proved to be capable of predicting most patterns in species diversity, although at the family level more information was lost than at the genus level. Roy *et al.* (1996) also found that patterns at the genus and family levels were significantly correlated to patterns in species diversity, and suggested that the usefulness of either genus- or family-level data as surrogates for species-level information depends on the resolution required to address the specific question. Similarly, Phillips *et al.* (1997) showed the danger of over-summarising species-level data for marine macroalgae. The choice of which taxonomic rank to use as a surrogate in a biological survey has to be a compromise between resolving patterns in diversity and the survey cost. Both the survey costs and the predictive value of the relationship between taxonomic levels will decline at progressively higher taxonomic ranks (Williams and Gaston 1996).

A major problem with measuring higher taxon richness is that species are not evenly distributed amongst higher taxa (Gaston 1996). The ability of higher taxonomic data to predict patterns in species diversity is hindered in biotic groups where many taxa at low taxonomic levels are included in one or only a few higher taxonomic levels (for example Prance 1994; Anderson 1995). This was a problem for the fish in our present study, because most were included in the order Perciformes. A low species:genus/family/Order ratio is advantageous if a higher taxon is to be used to predict patterns in species diversity. Unfortunately, a low ratio limits the value of higher taxonomic levels as surrogates to reduce taxonomic effort in describing species.

The significance of spatial scale is probably very important. In this study, our spatially restricted survey (Hamelin Bay) yielded a greater correlation between species-level data and higher taxonomic information than the larger-scale surveys (South Coast and Capes). In his study, Anderson (1995) noticed that the correlation between species and genus richness was strong within regions, but varied substantially between regions. Similarly, Vanderklift *et al.* (1998) stated that the ability of higher taxonomic levels to reflect the distribution patterns of species is likely to depend on the size of the total area surveyed, and the size of individual units. Differences in the species compositions of different areas are likely to be more substantial at larger scales, and so there are also likely to be greater differences in higher taxa.

CONCLUSIONS

An effective surrogate for conducting biological surveys in marine areas of south-western Australia would be a useful tool for marine conservation planners. In this study, habitat was established as an effective surrogate. Certain types of habitat information predicted patterns in species diversity in benthic assemblages. The higher taxonomic levels of genus and family also proved an effective surrogate. Sampling at the levels of either genus or family, depending on the compromise needed between survey time and cost and resolution of the results, would be more cost-effective than identification to species.

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INFORMATION REQUIREMENTS FOR DESIGNING EVALUATIONS OF MANAGEMENT EFFECTIVENESS FOR MARINE PROTECTED AREAS: AN INDONESIAN CASE STUDY

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Abstract

Marine protected area (MPA) managers are under increasing pressure from stakeholders to demonstrate that the design and the management of MPAs are achieving their objectives. There is general agreement amongst managers and stakeholders that some kind of assessment must be done to pinpoint the strengths and weaknesses of ongoing management processes in order to justify and guide future management decisions. The management of MPAs is, however, complex and a system to evaluate the performance of that management must suit local information needs and circumstances. Some recent progress has been made in developing useful guidelines to help managers focus on the suite of questions that need to be asked during a comprehensive evaluation of management effectiveness in order to inform adaptive management over time. The information requirements of such a system are potentially vast and they depend largely on the perceptions of the stakeholders (such as managers, politicians, conservationists, users, scientists, government agencies, communities and other special interest groups), each of whom have their own distinct views on what information is most meaningful and understandable. Managers thus face a challenge in deciding how to design and implement an iterative performance assessment process that will satisfy their information needs and those of their various stakeholders. This paper presents some preliminary research on the information requirements of a range of stakeholders at Bunaken National Park in Indonesia. Results suggest that stakeholders are interested in a range of performance information that goes well beyond the conventional foci of biological and socio-economic indicators. In order to ensure that a future evaluation of management at Bunaken National park is meaningful, it should: incorporate indicators that are chosen by stakeholders; 2) consider achievements relative to an actual starting point and the park's objectives; and 3) be interpreted in the context of the site-specific challenges and opportunities.

Keywords: information requirements, Indonesia, management effectiveness, performance assessment, evaluation

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INTRODUCTION

In the face of widespread habitat degradation and continuously increasing demands for access to marine resources, marine protected areas (MPAs) are becoming popular tools for conserving and sustainably managing marine environments (NRC 2001). There has been intense interest around the globe in determining whether or not MPAs are effective – as a management tool generally (White 1986; Jones *et al*. 1992; Jameson *et al*. 2002; Halpern 2003) and as a means of dealing with site-specific issues (eg, White 1986; Pollnac *et al*. 2000; Fauzi and Buchary 2002). The role of evaluation is extremely important in providing relevant information to determine if MPA management is effective – that is, if the design and management strategies are achieving their goals (Kelleher 1999; Salm *et al*. 2000). Over time, as social and environmental contexts change, management strategies must be adapted to respond to continuously changing issues and needs. Regular evaluation is a crucial element of that adaptive process because it can provide insight on how specific elements of management might be best adapted and improved in light of changing conditions (Holling 1978; Salafsky *et al*. 2001). Evaluation can also help to justify and guide future management decisions for individual MPAs (Agardy 1995; Kelleher 1999; Stolton and Dudley 1999; Salm *et al.* 2000; GCFI 2001; NRC 2001).

There are many reasons to evaluate management effectiveness of MPAs. Some of the most common ones are reporting for purposes of accountability and advocacy, planning for the purposes of developing policy or allocating resources, and adapting management strategies to reflect changing conditions and better achieve management objectives (Hockings and Phillips 1999; Hockings *et al*. 2000; Mangubhai 2003; Pomeroy *et al*. in prep). Regardless of the purpose of a particular evaluation or monitoring program, the first step in ensuring that the eventual results will be meaningful is to determine the information requirements (Crosby and Milon 2000; Salafsky *et al*. 2001) - who will be using the results and what they want to know (Margoluis and Salafsky 1998). The information requirements of an evaluation of management effectiveness are potentially vast and may need to cover a range of management elements such as contextual issues, planning, available resources, management processes and management outputs and outcomes in order to provide adequate information to gauge progress and assess effectiveness (Kelleher 1999; Hockings *et al*. 2000). The appropriate focus of each individual evaluation depends largely on the priorities of managers (Hockings *et al.* 2000) and perceptions of the stakeholders (such as managers, politicians, conservationists, users, scientists, government agencies, communities and other special interest groups), each of whom will have their own distinct views on what information is most meaningful and useful. In addition to this variability in views and values, each MPA has its own specific objectives (whether explicitly stated, agreed upon, or not) and faces its own specific management challenges based on local circumstances. Some recent progress has been made in developing useful guidelines to help managers focus on the suite of questions that need to be asked as part of a comprehensive evaluation in order to inform adaptive management over time (e.g. Kelleher 1999; Hockings *et al.* 2000; WCPA and WWF 2002; Mangubhai 2003; Pomeroy in prep.). These guidelines emphasise that each protected area is different and may warrant a different focus or approach to such an evaluation depending on local conditions and needs.

The idea of collecting data to evaluate MPAs and their effects is not new. Many studies and some reviews have been conducted to identify the type and extent of MPA impacts on internal and adjacent environments (e.g. Roberts and Polunin 1991; Alder 1996; Pollnac *et al* 2000; references within Halpern and Warner 2002; Halpern 2003). Most of these authors have also attempted, on the basis of their measurements, to identify how generally 'effective' or 'successful' MPAs have been (Roberts and Polunin 1991; Alder 1996; Pollnac *et al.* 2000; Halpern and Warner 2002; Halpern 2003). The purposes of these studies, the intended audiences for the results, and the working definitions of 'effective' or 'successful' differ considerably – creating confusion for practitioners who are looking for information or lessons that are relevant to their task of adapting ongoing management.

The variety of definitions and criteria for 'effective' or 'successful' MPAs is illustrated in the literature. Roberts and Polunin (1991) and Dugan and Davis (1993) reviewed studies on the impacts of MPAs on fisheries resources in order to demonstrate their 'efficacy' in providing benefits to fishing industries. Ticco (1995) surveyed practitioners around the world to identify factors related to why MPAs are 'successful' or 'nonsuccessful [sic]' at protecting biological diversity. Alder (1996) surveyed practitioners on the 'perceived success' of MPAs throughout the tropics in order to develop a 'baseline for measuring future developments in MPA management planning'. Pollnac *et al.* (2000) investigated socio-economic factors that influence 'success' of MPAs in order to improve the design and placement of new MPA projects. Halpern (2003) reviewed studies on MPAs in order to 'assess the effectiveness' of MPAs according to four biological measures – diversity, density, biomass and size of a range of species. Christie *et al.* (in press) investigated the 'success' of small community-based MPAs in improving fisheries resources outside their boundaries. Each of these studies applies a different definition of 'effectiveness' and/or 'success' and each is aimed at a different audience. All of these authors claim that their studies are useful in improving management or decision-making processes and all of them draw conclusions regarding how 'effective' or 'successful' MPAs have been or can be. None of these studies, however, mention site-specific objectives or actual management strategies with reference to some initial starting point within the context of site-specific challenges and obstacles. References to studies summarising data collection that is focussed on providing information relevant to the specific needs of MPA managers and adaptive management are more difficult to find because; they tend to come in the form of local consultancy reports or site-specific reviews for individual MPAs and, as such, they do not usually reach the primary literature (e.g. NOAA *et al.* 2000; NOAA *et al.* 2002).

A research project is currently being conducted to identify stakeholders' information requirements as part of the design phase of an evaluation of management effectiveness for the purpose of informing the adaptive management of Bunaken National Park (BNP) in North Sulawesi, Indonesia. A combination of scientific[1] approaches and participatory[2] approaches are being used to develop an evaluation program that will provide answers to the kinds of questions

[1] The term 'science' here includes both natural and social science fields, both of which can involve participatory processes in their methods for data collection and analyses.

[2] The term 'participation' here means involvement of stakeholders (including scientists and/or non-scientists) in data collection and decision-making processes.

that managers and stakeholders think are important. In this paper I present some preliminary results on the information requirements of BNP stakeholders and I discuss the significance of these information needs in the context of designing and implementing an evaluation at this site. Some suggestions are made for designing and implementing an appropriate, meaningful and feasible evaluation of management effectiveness for BNP.

METHODS

Study site

Bunaken National Park (BNP) is a marine protected area on the coast of North Sulawesi, Indonesia. It was declared a national park in 1991 on the basis of its high conservation value and the global significance of its underwater geological structures, coral and mangrove diversity, fish diversity, abundance of rare species and its aesthetic and educational values (Anon. 1996). Prior to that, the area had been declared a local and provincial protected area but there was no organised management authority in place to coordinate activities or enforce regulations in the park. A 25-year management plan was published in 1996 and a managing authority, including rangers, and limited funds were then provided by the national government to implement the management plan. There are more than 30,000 villagers living in the 22 villages within the park and many more adjacent to the boundaries, most of whom depend largely on extracting natural resources from the park or nearby for their livelihoods.

Long-standing management challenges at BNP include the following: cultural conflicts and mistrust amongst local stakeholders and managers; damaging fishing and farming practices; rapid and poorly planned coastal development; unethical business and political practices; corrupt law enforcement systems; and unorganised management strategies. In 2000, increasing demand from stakeholders for fair and accountable management led to the development of a representative management advisory board to manage the newly established entrance-fee system and coordinate patrols as well as conservation and development activities in the park. Since the board's inception, management processes have become more transparent and participatory, management outputs have increased dramatically and positive outcomes from management are becoming clear to local communities, but many management challenges remain (Dahl-Tacconi 2003).

There are a number of organised (or semi-organised) stakeholder groups present in and around BNP in addition to several geographically distinct communities and socio-economically distinct business operators and occupations. In addition, there are three distinct bodies directly involved with management activities in the park: the Balai Taman Nasional Bunaken (BTNB, the national park management authority), the Dewan Pengelolaan Taman Nasional Bunaken (DPTNB, the representative management advisory board), and the Forum Masyarakat Taman Nasional Bunaken (FMTNB, the community forum). A number of other stakeholders participate directly in management activities via participatory conservation programs and/or indirectly in management decision-making processes via their representative on the advisory board.

The survey questionnaire

To determine the kind of information needed to adapt and improve management of BNP, a semi-structured interview was used with managers and other stakeholders to solicit their perceptions on the values in the park and the threats to those values, their vision of what a successful BNP would be like, their priorities for focal points of an evaluation of management, and their opinions on the relative importance of potential indicators of 'success' as they themselves defined it. The questionnaire included three open-ended questions and three rating exercises. The questionnaire was initially written in English and then translated into Indonesian. It was pilot tested with several respondents to ensure that the questions were clear and understandable and that the average interview time was appropriate. Respondents were generally interviewed individually by two interviewers (one leading the interview and the other observing, each taking notes). Both interviewers then worked together to enter the data and categorise answers from each interview.

Respondents were asked to describe what they think are the most important values in the park and what they think are the possible or existing threats to those values. Respondents were free to provide multiple answers to these open-ended questions. Their answers were recorded in detail at the time of the interview and later labelled according to categories of values and categories of threats, which were developed after the interviews. The total number of responses falling into each category was then recorded to provide an indication of how often respondents referred to a particular group of issues. Responses were categorised according to the issues, behaviours or attitudes that were mentioned specifically. No extrapolation or implied cause-effect relationship was imposed by the researcher in processing the data. For example, if one respondent specifically mentioned bomb-fishing, cyanide fishing, fishing in protected zones, rubbish on the beach, and too many non-locals working in the park, then data for views on threats from that respondent would read as follows: 'destructive and/or illegal fishing activities' (3); 'Careless handling of solid waste, fuels and other pollutants' (1); and 'Influx of outsiders' (1). No assumptions were made about their views on the underlying causes of the problems.

Interviewers then asked the respondents to describe their vision of what a successful BNP would be like in the future. Their answers were recorded in full and later categorised (using predetermined categories) according to what kinds of terms they used to describe success. The categories used were 'planning activities', 'financial and technical inputs', 'management processes', 'outputs', and 'outcomes'. The 'outcomes' category was further divided into 'biological/ecological', 'economic', 'social shift or behavioural change', 'changes in awareness'. For example, if a respondent said that "BNP would be a success in the future if management was well-funded and participatory", then data for vision of success from that respondent would read as follows: 'inputs' (1) and 'processes' (1) because the respondent defined success in terms of both financial inputs and management processes.

Respondents were then asked to review a list of 31 potential indicators of success and rate the importance of each along a three-level scale ('critical to success', 'important for success', 'unimportant'). Lastly respondents reviewed a list of six different questions, each representing a different focus of evaluation, and rated each question according to how important ('very important', 'important', 'unimportant') they thought it was in determining management effectiveness of BNP. They were also asked to rank one of the questions as 'the most important'. Respondents who found it too difficult to choose only one were allowed to indicate two of the options as 'most important'.

The respondents

In an effort to survey a broad range of stakeholders and identify the full range of information requirements for a performance assessment, I consulted the advisory board's executive secretariat and members of the advisory board in order to develop a list of the various stakeholders and stakeholder groups in the park. I then chose a target number to be surveyed from each group after considering the following issues: the composition of the primary audience chosen for the evaluation; the size of the groups; the relative similarities amongst some of them; the limited available time to spend interviewing; and the higher priority on including at least some representatives from all stakeholder groups rather than a large sample from any particular one. Sampling began with members of the management advisory board, which is meant to be representative of the range of stakeholders in the park.

The results presented here are based on a preliminary data set and, at the time of writing, interviewing was not yet complete. No advanced or statistical analyses have been conducted on this small data set. The results will be explored more thoroughly when interviews are finished.

RESULTS

The survey respondents

So far, 24 respondents have been interviewed. These respondents are mostly people who are directly or closely involved in management planning and management decisions. The profile of these respondents is thus not representative of all stakeholders in the park. Notably missing are three major stakeholder groups – the rangers (mostly non-locals who are present to enforce regulations), the local residents (living inside the park, some of whom participate in joint patrols) and the business operators in and near the park (including locals, non-locals and foreigners). The results presented here do not yet represent their views, so conclusions cannot be made regarding their specific information requirements or how information requirements of any single stakeholder group compare with others.

Values of Bunaken National Park

When asked to list the most important values and/or resources in Bunaken National Park, the majority of respondents mentioned biological diversity. When asked to explain what kind of biological diversity they meant, most respondents struggled to elaborate and some explained that they had simply read or heard somewhere that it was important but were not sure why. Other common responses included coral reefs and reef fish, mangroves, dugongs and other rare or endemic species (Table 1).

Threats to the values of Bunaken National Park

The most commonly mentioned threats to the values in the park were destructive and/or illegal fishing practices (Table 2). Nearly all respondents referred to bombing and cyanide specifically (the topics of the most widely publicised and long-running conservation campaign in the area). Another commonly mentioned group of threats included references to a poorly controlled tourism sector along with damage from careless tourists and divers. Some less commonly mentioned threats included poorly planned and unsustainable coastal development, poor waste management, mangrove cutting and coral mining. Surprisingly, some significant threats were hardly mentioned and their underlying causes were rarely brought up. For example, no respondents replied that lack of awareness was a serious threat.

Visions of success for Bunaken National Park

When asked to describe their vision of what would be a successful BNP, respondents were able to answer surprisingly quickly and succinctly. Only two respondents felt the need to list a number of indicators and most appeared to be content with just one that adequately represented their view of a successful park. Most respondents described an outcome or on-ground impact that they hoped for. The majority of those responses described some kind of change in social behaviours or increase in awareness (e.g. "stakeholders are using sustainable practices" and "communities are educated about conservation and sustainability issues") (Fig. 1). Biological/ecological outcomes (such as "increased coral cover and fish abundances") and economic outcomes (such as "benefits of increasing tourism are shared with local communities") were mentioned much less frequently than other kinds of outcomes. Many

Table 1. Views of 24 stakeholders on the most important values and/or resources of Bunaken National Park.

Most commonly mentioned (10-20 responses)	Less commonly mentioned (5-9 responses)	Other (1-4 responses)
corals and reefs (20)	traditional culture (9)	turtles and rays (4)
rare and endemic species (15)	unusual geological features and oceanographic conditions (6)	intact natural processes and undisturbed areas (4)
dugongs (15)	clear water (6)	recreational values (4)
mangroves (15)	coelacanth (6)	seagrasses (4)
species diversity (13)	popular tourist destination (5)	tropical forests (4)
reef fish (12)	-	food fish (3)
habitat diversity (10)	-	pelagic fishes (2)
-	-	educational and research values (2)
-	-	critical habitats for important species (2)
-	-	source of local income (1)
-	-	seaweed [for farming] (1)
-	-	global heritage significance (1)

Table 2. Views of 24 stakeholders on the most serious threats to the values and/or resources of Bunaken National Park. In parentheses is the number of times each type of threat was specifically mentioned during the 24 interviews.

Most commonly mentioned (50-90 times)	Less commonly mentioned (10-49 times)	Others (1-9 times)
destructive and illegal fishing practices (87)	rapid and unsustainable coastal development (28)	influx of outsiders living and working in the park (7)
poorly controlled operational standards for tourism industry and damaging tourist behaviour (52)	careless handling of solid waste, fuels and other pollutants (20)	greed and irresponsibility (5)
	mangrove cutting (20)	perverse economic incentives to participate in illegal or unethical practices (4)
-	coral mining (16)	population growth (4)
-	hunting and collecting of protected species [other than fish] (11)	cultural focus on cash and resource extraction (3)
-	natural phenomena [including bleaching and storms] (11)	ornamental fish trade (3)
-	-	poor land use management (2)
-	-	influence of western cultures (2)
-	-	lack of interest in traditions (1)
-	-	seaweed farming (1)
-	-	market demands and fluctuations (1)
-	-	forest fires (1)

responses referred to the management process itself and conduct of managers (e.g. "management is participatory" and "management is ethical"). Very few respondents referred to management planning, issues regarding resources, or management outputs while describing their initial vision of a successful BNP.

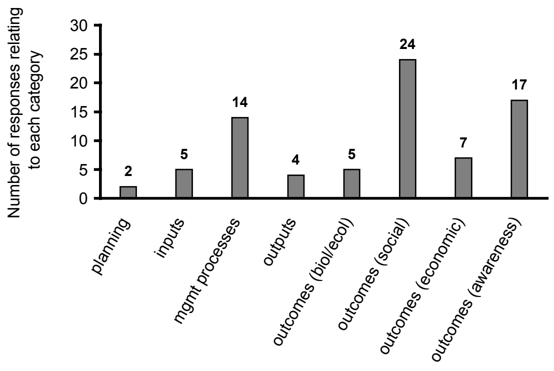

Fig. 1. The 24 respondents were asked, "Please describe your vision of what a successful BNP would be. Start with 'BNP would be a success in the future if …'". Each of their descriptions was categorised according to which element of management it related. (Some respondents offered descriptions relating to several different elements of management).

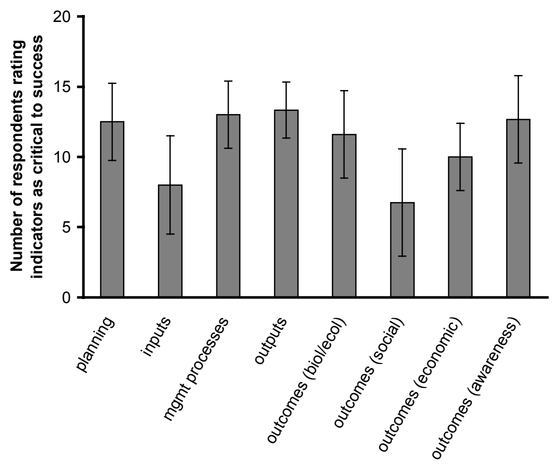

Fig. 2. Stakeholders' views on the kinds of indicators that are most critical to determine the success of Bunaken National Park. The 24 respondents were asked to rate the importance of a variety of different kinds of indicators (several in each category). Results indicate that respondents place critical importance in a variety of different indicators of success - spanning across all elements of management and types of outcomes. Sample mean error bars show that within most categories, indicators were not rated equally.

Table. 3. Views of 24 stakeholders regarding the importance of different questions in determining the success of Bunaken National Park. Each question was rated according to a scale from 'unimportant' to 'very important'. Then respondents were asked to choose the (one or two) most important question(s) in determining success.

Question	'un-important'	'important'	'very important'	'most important'
What is the current status of the values and threats in the park? (**social and environmental context**)	0	4	**20**	7
How adequate are current laws, policies and plans for managing the park? (**planning**)	0	9	**15**	4
How adequate are the currently available resources for managing the park? (**inputs**)	0	11	**13**	1
How appropriate are the current management processes and activities? (**management processes**)	0	**13**	11	4
How much of the management plan has been implemented and what products and services has management delivered? (**outputs**)	3	10	**11**	4
What impact has management had on the values and threats in the park? (**outcomes**)	0	8	**16**	**12**

Priorities regarding indicators of success

The respondents rated the importance of 31 different possible indicators of success according to how important they felt each was to the overall success of the park ('critical to success', 'important for success', and 'unimportant'). The list of indicators covered a range of issues in the areas of planning, inputs, processes, outputs and outcomes. Very few respondents rated any of the indicators as "unimportant". There was no single category of indicators which appeared notably more important than the others (Fig. 2). Regarding interests in indicators, there appears to be more variation of opinions about importance within categories than between them.

Priorities regarding questions for investigating performance

Respondents rated the importance of six different questions (each focussed on a different element of management) according to how important ('very important', 'important' and 'unimportant') they felt each question was in determining the success of BNP. The ratings show respondents generally felt all these questions are relevant to determining the success of the BNP (Table 3). After rating each of the questions, most respondents had difficulties in choosing only one that was a top priority. Each question was considered 'the most important' by at least one respondent. The majority of respondents indicated that questions relating to the status of the natural environment and impacts of management were the most pressing.

DISCUSSION

Initial results from this study indicate that the most commonly recognised values and threats in BNP are closely associated with management's current strategies for improvements, which are focussed on combating destructive fishing practices and working with partners to improve the sustainability of coastal development.

According to the initial responses of stakeholders in this study, a successful BNP would be most commonly characterised by positive social change, increased awareness and appropriate management processes. These results suggest that a definition of success for the purposes of implementing a meaningful evaluation of the effectiveness of BNP, may be quite different than the various definitions of successful and effective MPAs found in the literature. Definitions based on recruitment of fish (as in Roberts and Polunin, 1991), quantitative scientific evidence of protection[3] (as in Ticco, 1995), or exclusively biological features (as in Halpern and Warner, 2002 or Halpern, 2003) would not seem to be adequate in the case of BNP. Other approaches to defining success, which use a combination of criteria relevant to a specific site, may be more appropriate for BNP. For example, NOAA *et al.* (2000) defined 'effectiveness' according to their own site's characteristics and they use a list of criteria (including coral cover, algal cover, fish and lobster size and abundance, compliance, and stakeholder perceptions of values), worded as hypotheses, to determine how effective management has been. Alternatively, Pollnac *et al al*. (2000) used an index of overall 'success' that was calculated from a combination of factors: improvements in coral quality; perceived improvements of resources by communities; delivery of common management outputs; high compliance and empowerment of local communities. Despite the obvious biological focus of his reviews, Halpern (2003) acknowledged that evaluations of effectiveness will have different meaning for different people according to their situations. He states that "success of a marine reserve …will always be judged against the expectations for that reserve, and so we must keep in mind the goals of a reserve in its design, management, and evaluation" (Halpern 2003). Results from this study also suggest that the expectations of a variety of stakeholders and their views on what would constitute 'success' should be considered in order to streamline monitoring, focus reporting efforts and maintain more meaningful communications with those stakeholders.

Preliminary results from this study demonstrate that stakeholders closely involved with management at BNP are interested in the inputs, processes and outputs of management as well as biological, social and economic outcomes in determining the success of the park. This wide range of interests suggests that a large variety of questions needs to be investigated in order to provide an adequate assessment of the progress of management, which can then lead to appropriate and acceptable improvements and eventually achievement of more objectives. These findings are consistent with the recommendations of the IUCN Guidelines for Marine Protected Areas (Kelleher 1999), with the principles behind the IUCN Guidelines for measuring management effectiveness of protected areas (Hockings *et al.* 2000), and with the findings of Crawford *et al.* (2000), which were applied by Pollnac *et al.* (2000), who used a combination of natural and social science measures, local perceptions and expert opinions to examine success from a number of angles.

Many researchers and authors explicitly mention the value and importance of communicating with stakeholders about methods and results as well as encouraging stakeholders to participate in processes of data collection and analyses (e.g. Crawford *et al* 1998; Kelleher 1999; Crosby and Milon 2000; Salm *et al* 2000; Bunce *et al* 2001; NRC

[3] Ticco does not reveal what parameters have been included or what is meant by 'protected'. He does however acknowledge that the nature of reserves depends on their objectives and since those objectives vary globally, no single model for MPA management would be appropriate for all of them.

2001; Lawrence 2002;). There are far fewer references, however, that promote involving a wide range of stakeholders in determining the focus or specific lines of enquiry for studies and assessments (e.g. Crawford *et al* 2000; Bunce *et al* 2001; Lawrence 2002) even though there is evidence to suggest that cooperation and compliance is generally higher when stakeholders feel they have had an influential role in decision-making processes (Hanna 1998).

Ample evidence is available to indicate that MPAs provide increased abundances and sizes of targeted fish or shellfish species around the world and (Halpern in press and others). The studies that back this claim are generally focussed on benefits to fishermen – traditionally the strongest opponents of MPAs – and support the use of MPAs based on indicators of the status of current examples. The possibility remains that no amount of evidence will ever be enough to change the natural human tendency to exploit resources unsustainably (Ludwig *et al.* 1993). If managers and governments intend to actually improve the benefits and success of individual MPAs by managing effectively and adaptively to overcome local obstacles, the focus of research on MPAs will need to shift away from the traditional use of indicators focussed on measuring the status of fisheries resources and begin to make use of indicators focussed on measuring the progress of all elements of management (as recommended by Kelleher 1999 and Hockings *et al.* 2000) in order to better inform site-specific decision-making processes. "The science done for an MPA has to be driven by management needs" (Kelleher 1999).

RECOMMENDATIONS

In order for the upcoming evaluation of management effectiveness for BNP to be useful and meaningful, it should: 1) focus on progress of management achievements from a social perspective in addition to the status of environmental resources from a biological perspective; 2) incorporate analyses that include reference to a true historical starting point and an actual set of goals/objectives; and 3) be interpreted in the context of the specific challenges and opportunities present at BNP. Choosing the most appropriate indicators will require some careful consultation and planning to ensure that they are relevant, appropriate and feasible. Most importantly, it will be critical that the indicators produce information that is meaningful for adapting and improving management.

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ASSESSMENT OF HABITAT FUNCTION – A CASE STUDY IN ESTUARINE FISH HABITAT CREATION

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Abstract

Fish Habitat Areas (FHAs) are declared in many Queensland estuaries to manage critical fisheries resources such as breeding and nursery habitats. Effective protection of this type of Aquatic Protected Area (APA) from dredging impacts may require a suite of management tools, and effective assessment of the success of mitigation measures. A recent dredging program near the Noosa River FHA provided a case study for an ecological evaluation of various mitigation options. A 1999 impact assessment study examined the effectiveness of a 40 m buffer zone between dredging and the FHA boundary using macrobenthic infauna as an ecological indicator. Impacts were detected within the FHA, suggesting that buffering is insufficient protection. An artificial intertidal habitat was also constructed in the estuary as an alternative means to achieve 'no net loss' of fisheries productivity. The present study examined the effectiveness of the artificial area in offsetting the loss of shallow-water foraging habitats altered by dredging. The study (*i*) compared production of benthic-feeding fisheries species among artificial, natural, FHA and impacted habitats; (*ii*) determined physical processes influencing colonisation by benthic prey species; and (*iii*) investigated natural temporal variations in faunal use of sandy intertidal habitats. The outcomes will include an ecological assessment of alternative methods of habitat protection, and development of valid methods of comparing habitat functions. Preliminary results and conclusions are presented and discussed.

Keywords: habitat creation, fisheries, estuarine, experimental

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INTRODUCTION

Assessment of habitat function in artificial habitats

Effective management of aquatic areas is greatly enhanced if managers are able to assess habitat performance and habitat values quantitatively. Aquatic habitats are subject to loss, degradation and damage due to a range of coastal development activities, such as vegetation clearing, dredging, filling of floodplains and concentration of stormwater flows. Management of these aquatic habitats requires a suite of strategies, including conservation through declaration of Aquatic Protected Areas (APAs) and/or restriction of development activities by means of management plans.

Where habitat loss is unavoidable, 'no net loss' policies may be adopted. The 'no net loss' concept implies that where a habitat is destroyed or altered, at least an equivalent area must be created elsewhere, using rehabilitation or habitat creation techniques, in an attempt to replace valuable habitat functions (Hancock 1993; Minns 1997; Shabman 1998). Thus habitat creation and rehabilitation are used as tools to mitigate disturbances to aquatic habitats (Hancock 1993; Matthews and Minello 1994; Weinstein 1996; Zedler *et al.* 1998).

The ever-increasing interest in artificial aquatic habitats worldwide has necessitated a critical review of the approaches taken to assess ecological performance of these habitats and to address some of the limitations of previous approaches.

Many attempts at creating and assessing artificial habitats have been made worldwide in a range of systems, including mangrove forests (Llanso *et al.* 1998; Roennbaeck *et al.* 1999), seagrass beds (Fonseca *et al.* 1990; Jenkins and Sutherland 1997; Jenkins *et al.* 1998; Henderson 1999), saltmarshes (Minello and Zimmerman 1992; Levin *et al.* 1996; Simenstead and Thom 1996; Minello and Webb 1997; Posey *et al.*1997), reefs (Bortone *et al.* 1997; Rooker *et al.* 1997; Kellison and Sedberry 1998; Tupper and Hunte 1998; Aseltine-Neilson 1999; Fowler *et al.* 1999), subtidal spoil deposits (Flemer *et al.* 1997, Hall and Frid 1997) and freshwater streams (Hilderbrand *et al.* 1997; Wilber and Bass 1998).

Despite the interest in habitat creation and rehabilitation, many artificial habitats do not appear to achieve similarity with the natural systems they are meant to replace or rehabilitate (Minello and Webb 1993). Dissimilarities often exist in fairly fundamental physical and biological characteristics (Levin *et al.* 1996; Simenstead and Thom 1996). The vegetation and invertebrate communities are often different in terms of abundance and composition (Matthews and Minello 1994; Levin *et al.* 1996; Minello and Webb 1997; Posey *et al.* 1997; Dayton *et al.* 1998; Henderson 1999). Where artificial habitats have been shown to be similar to the natural environment, it has usually been in terms of fish standing stocks (Fonseca *et al.* 1990; Minello and Zimmerman 1992; Llanso *et al.* 1998; Ambrose and Meffert 1999; Sheridan and Minello 1999), although the reverse has also been reported (Brown-Peterson *et al.* 1993).

Empirical evidence from artificial reefs suggests that new areas or structures are quickly colonised by large numbers of highly mobile predatory fish (Fujita *et al.* 1996). However, presence of fish at a site cannot be taken as evidence of long-term sustainable fish populations, particularly if invertebrate prey are not available. Furthermore, a focus on the fish community fails to address the broader implications of sustainability, which should include other components of the system. The extent to which these habitats achieve the objective of replacing desired habitat functions is often difficult to resolve because the approach taken to assess habitat functioning is flawed scientifically.

Defining desired habitat functions

The fundamental objective of habitat creation and rehabilitation attempts for 'no net loss' purposes is to preserve a desired function or suite of functions, such as maintenance of biodiversity within a bioregion, production of commercial species (e.g. fisheries), or protection of endangered species (e.g. dugong) (Minns 1997). Aquatic habitats, particularly those in estuaries, fulfil a range of functional roles in the life cycles of many species. Estuaries are highly productive areas that export significant quantities of nutrients and energy into the marine environment (Odum and Heald 1972; Goulter and Allaway 1979; Bell *et al.* 1984; Hoss and Thayer 1993). Estuaries are also critical nursery areas for many species of inshore and offshore fish and crustaceans, supporting a diverse and abundant source of food items suitable for juvenile stages and providing shelter from predation in the form of shallow, turbid water and a high degree of structural complexity (Blaber and Blaber 1980; Lasiak 1986; Vance *et al.* 1990; Kailola *et al.* 1993; Edgar and Shaw 1995a, 1995c; Bishop and Khan 1999).

In the majority of cases, the habitat function of most interest to management is the ability of the habitat to produce fauna successfully. Managers therefore require a valid system for measuring and assessing habitat function in aquatic areas, and in particular the ability of the site to support fauna.

Previous attempts to assess habitat function in created sites

Previous approaches for assessing and comparing the function of created habitats with natural areas were mainly concerned with measurements of structural and floral characteristics. Recruitment and survival of prey items and establishment of higher trophic levels are rarely examined (Levin *et al.* 1996; Simenstead and Thom 1996; Minello and Webb 1997). An inventory of constructed and rehabilitated wetlands in the USA by Matthews and Minello (1994) revealed that only 23 of a total of 787 marshes monitored had been investigated for use by fauna. The assessment of artificial habitats in general has been criticised as being deficient in non-botanical performance indicators such benthos and demersal fish, and lacking in experimental testing (Levin *et al.* 1996; Simenstead and Thom 1996).

This focus on measures of variables relating to physical structure is based on an incorrect assumption that there is a direct and predictable link between structural complexity and habitat function. Unfortunately, the links between structural components, biological components and ecological functioning of a habitat are not sufficiently understood, especially in the marine environment, to confidently use structural or demographic attributes as surrogate measures of habitat function. As defined above, the aim of 'no net loss' policy is to replace specific habitat functions. Assessment of the success of such policies must therefore focus on measures of habitat function, such as growth, survival and trophic exchange, unless there is a clear and predictable relationship between structural complexity and function.

A focus on simple measures such as physical structure that may not provide any assessment of the success of habitat-creation schemes has partly come about through limitations in management. Management plans generally cover extensive areas, at the scale of entire estuaries or chains of offshore reefs, and management agencies have limited resources to conduct investigations. Such constraints have resulted in a preference for simple, easily measured criteria for assessing and comparing the performance of aquatic habitats (e.g. width of mangrove zone, number of species present, rareness of the habitat type, etc.). The information available to management is therefore usually in the form of remotely sensed monitoring data with varying degrees of ground-truthing. These simplistic measurements are suitable for measuring the structural attributes of a site, but are not useful for gathering data on the mobile fauna.

Several categories of performance criteria used to compare habitat values between estuarine areas may be defined. Many of these approaches are 'single component' only (i.e. they focus upon a single trophic level) and may be broadly described as (*i*) vegetation-only surveys, (*ii*) benthos surveys, (*iii*) nekton surveys including estimates of size and condition, (*iv*) concurrent surveys of benthos plus nekton, and (*v*) experimental tests of nekton feeding.

Structural features of the habitat, including physical and chemical features, are important in understanding ecological processes if these are linked to concurrent information on the density, growth rates and survivorship of fauna using that habitat. Surveys of vegetation may provide information on the primary production potential of the habitat, in addition to indicating the structures available as substrata and refuge for fauna. Replacement of the structural characteristics of the plants and the substratum does not, however, guarantee that a site is capable of supporting the target fauna. Many other factors determine faunal distribution, such as the proximity to linked habitats (Irlandi 1994; Irlandi and Crawford 1997), the presence of suitable food (e.g. Blaber and Blaber 1980; Connolly 1994; Edgar 1994; Edgar and Shaw 1995b, 1995c, Levin *et al.* 1997;McIvor and Odum 1988), structural complexity (Williamson *et al.* 1994; Eclöv 1997; Jenkins and Wheatley 1998), transport of planktonic propagules (Fairweather 1991) and invasions by opportunistic species. Desired ecological functions, particularly the ability of the site to support fauna, cannot be extrapolated from simple vegetation surveys.

Benthic faunal surveys are important because they provide information on a critical source of food for trophic consumers in estuaries. Benthic fauna link the created habitat substrata, detritus-based food chains and larger carnivores (Posey *et al.* 1997; Henderson 1999). The presence of benthic assemblages demonstrates that a site is able to support fauna lower down in the food web and indicates that potential prey are available for higher-order predators. However, the value of the site to higher-order predators cannot be extrapolated solely from the presence of available food. Fish may avoid certain habitats that support high densities of prey items for reasons connected with predator avoidance or foraging efficiency (Brewer and Warburton 1992; Connolly 1994). It is equally important to demonstrate that fish numbers using the created habitats are sustainable in these areas.

Examination of fish standing stock has been used as indicator of 'habitat value' in transplanted seagrass (Fonseca *et al.* 1990; Jenkins and Sutherland 1997), rehabilitated mangroves (Llanso *et al.* 1998), constructed *Spartina* marshes (Minello and Zimmerman 1992; Minello and Webb 1993), and artificial reefs. Surveys of fish distribution and abundance are frequently used to compare fish use between two or more different natural habitats, such as seagrass and bare sediments (Ferrell and Bell 1991; Hyndes *et al.* 1996; Wantiez *et al.* 1996; Halpin 1997; Duffy and Baltz 1998; Gray *et al.* 1998; Jenkins and Wheatley 1998; Rozas and Minello 1998), river and lagoon habitats (Aliaume *et al.* 1997), mangrove and adjacent waters (Morton 1990), and mangrove and seagrass habitats (Sheridan 1992; Pinto and Punchihewa 1996). Concurrent surveys of both fish and prey have been used to compare various artificial sites with natural areas and to compare natural seagrass and bare habitats (Brewer and Warburton 1992; Edgar 1994; Edgar and Shaw 1995a, 1995b, 1995c). Previous studies on the relationships between diet and prey densities have also been used as evidence for the success of habitat-creation schemes.

Despite the importance of information on use of the created habitats by fish and the availability of important resources such as food and shelter, this information alone still does not address the key issue of habitat function. Such information cannot be used to demonstrate that a created habitat will be able to support the fish communities or maintain local biodiversity, especially for the larger, mobile, carnivorous species that are often the focus for protection and management.

Comparisons between natural habitats and modified habitats such as canal estates have indicated that modified habitats are capable of attracting large and diverse fish assemblages but the productivity and sustainability of these areas are not necessarily comparable to natural habitats. Fish visiting such areas are highly mobile and may be present as transitory visitors. Examination of artificially simplified habitat (canal estates, marinas and piers) also suggests that certain estuarine species may use these areas instead of natural habitats, but again overall productivity may be less than in the natural habitat (Duffy-Anderson and Able 1999), and nursery functions may be lost or reduced (Williamson *et al.* 1994). Artificial reefs are frequently considered to simply aggregate fish rather than actually increase their production (Bortone 1998; Coll *et al.* 1998).

Similarly, estimates of the size and condition of nektonic species caught over a particular habitat cannot be directly linked to feeding at that habitat, because mobile predators tend to range widely between habitats, and several different foraging areas may contribute to the observed growth and condition of individuals. Recent growth, as estimated from otolith analysis, has been used as an indicator of 'rearing quality' of created and natural sloughs for chinook and coho salmon (Miller and Simenstead 1997), and to compare natural vegetated habitats such as saltmarshes (Baltz *et al.* 1998), seagrass beds (Rooker and Holt 1997; Rooker *et al.* 1999), and ranges of habitats including rocky reef, cobble, seagrass and sand (Tupper and Boutilier 1997). Those studies do not directly address the contribution of the compared habitats to fish production because they do not consider the trophic interactions occurring at the sites.

Direct measurement of the functional links of estuarine habitats in the form of contribution of the habitat to faunal growth and survival is rarely attempted (Beck *et al.* 2001). Few studies have incorporated measures of growth rates for fish foraging in different intertidal areas. Measurements of the rate of fish growth provide a direct measurement of the amount of nourishment potentially available at the habitat, and thus are valid indicators of habitat function (potential to produce consumers at a higher trophic level) that can be used as assessment of habitat value. Enclosure cages have been used to compare rate of growth of pinfish between 'seagrass / marsh' and 'deep channel / marsh' (Irlandi and Crawford 1997), pinfish between seagrass and bare sand (Levin *et al.* 1997), red drum between marsh, unvegetated bottom and oyster bed (Stunz *et al.* 1999), and flounder and tautog between areas covered by piers, open water, and transitional edge zones (Duffy-Anderson and Able 1999). However, these measurements are only on an experimental scale and can therefore only indicate the potential growth rates of fish if foraging in that area. Concurrent data on the extent of actual use of the habitat by nektonic fauna and the density of available prey items is still required to estimate the total contribution of the habitat to fish production.

Comparisons of faunal use of habitats often neglect problems of scale. Many comparisons of artificial and natural habitats do not take into account natural variability in the sampling design, and do not address the question of whether fish use habitats differently at different times. Previous comparisons of use by fish of created and natural habitats tended to be restricted to a few occasions per year for several years, or else monthly sampling (full or new moon only) within a single year (Fonseca *et al.* 1990; Brown-Peterson *et al.* 1993; Simenstead and Thom 1996; Minello and Webb 1997). However, the distribution and abundance of fish in natural estuarine habitats vary over time, according to environmental factors at several time scales, such as season, phase of the moon, stage of the tide and time of day (Wilson and Sheaves 2001; Morrison *et al.* 2002; Thompson and Mapstone 2002).

To address whether fish assemblages are different between natural and artificial sites, these variations in the distribution of fish must be taken into account. For example, an artificial site may be particularly important to newly recruiting larvae or to nocturnal species, but these fauna may not be recorded if sampling is restricted to daylight hours during the full moon. The interactive effect between season, month, lunar phase and time of day appears not to have been studied. Similarly, intertidal invertebrate assemblages within estuaries vary significantly at both large and small spatial scales (Morrisey *et al.* 1992a, 1992b; Underwood 1992, 1993, 1996; Thrush *et al.* 1997).

A new approach for assessing the success of created marine habitats

Valid comparison of ecological functions between estuarine habitats requires a comprehensive approach, focussing on assessment of the ability of the site to support and produce fauna. Demographic information on the biological assemblages using the habitats should include not only primary producers, but also first-order consumers in the form of relatively sedentary invertebrates, and larger, more mobile predators. In many cases, the primary interest from the viewpoint of resource managers will be in species from higher trophic levels, so it is essential to measure directly the extent of use by these groups when considering the value of a habitat. The number of juveniles using the site is also important in most estuarine areas where a significant function is provision of nursery habitat.

Management is usually concerned with substantial areas (scale of kilometres) that are permanent or long-term arrangements. Within these large scales there are many levels of variability in the marine environment. Faunal surveys must address this variability at different spatial and temporal scales, so that differences between habitats will not be confounded by natural variability in space and time. Sampling at a range of spatial scales will also allow the results of small-scale manipulative experiments to be meaningfully extrapolated to dimensions relevant to management.

Specific habitat functions such as faunal production can be measured only by directly examining ecological interactions. If the primary desirable attribute of an area is production of fish through provision of foraging habitat, then trophic interactions occurring in the habitat must be tested. The effectiveness of a feeding habitat may be measured by examining the ability of the habitat to contribute to fish growth. Trophic interactions may be investigated experimentally by measuring the growth rate and survival between habitats, to test the potential growth rate that may be obtained at a site. Small-scale experiments can then be linked to data on actual faunal use of the site.

NOOSA ESTUARY CASE STUDY

A created habitat, constructed as mitigation for a recent dredging program in the Noosa River estuary, provided a case study for an ecological assessment of the ability of a created site to support fauna.

Shallow estuarine sediments support high densities of macroinvertebrates important in the diet of fishery species using the estuary, and are known to function as feeding and spawning areas for several key species of commercial fish, for example whiting and baitfish species (Hyland 1993; Kailola *et al.* 1993). Dredging activities have the potential to affect significantly the faunal assemblages in these shallow sediments (Poiner and Kennedy 1984; Van Dolah 1996). In 1998, dredging was undertaken close to a declared Fish Habitat Area (FHA), a type of fisheries-management APA declared over many Queensland estuaries to manage critical fisheries resources such as breeding and nursery habitats. An assessment of impacts of these dredging works examined the effectiveness of a 40 m buffer zone between dredging and the FHA boundary, using macrobenthic infauna as an ecological indicator. Impacts were detected within the FHA, suggesting that buffering may be insufficient to achieve ‘no net loss’ of fisheries productivity (Skilleter unpublished). As another component of the mitigation measures for the dredging works, a large-scale ‘habitat exchange’ experiment was conducted with an intertidal fish-foraging habitat constructed from the dredge spoil to offset disturbances to the shallow-water sandbar habitats affected by dredging.

The project aims to determine whether the artificial foreshore from dredge spoil could be effective in faunal production by providing alternate foraging grounds for estuarine fish. The development of the created intertidal banks as functioning fisheries habitats was assessed by addressing the following questions:

1. Does the created habitat support suitable macrobenthic food for fish?
2. What physical processes are important in influencing colonisation of estuarine sediments by invertebrate animals (potential food for fish)?
3. Which prey species are most important in the diet of estuarine fish of economic importance?
4. Are fish assemblages and fish numbers in the created site similar to those in natural estuarine areas, and do fish use habitats in the same way at different times?
5. Are growth rates and survival of fish in the created habitat comparable with those in natural foraging areas?

Analyses are still in progress, but preliminary results are presented here to illustrate the importance of an integrated, detailed approach to measuring a specific ecological function: the ability of the site to support fauna by providing a foraging habitat for benthic-feeding fish.

STUDY SITE

The study area was within the lower Noosa River estuary (26°23.255'S,153°04.747'E), a dynamic and unstable system characterised by rapidly shifting sandbars and narrow channels (Stephens 1973). Tides are semidiurnal, with tidal ranges of 1.4 m near the mouth, 1.2 m at Munna Point, and 0.9 m at Tewantin. Tidal influence creates strong currents in the channels, and current velocities can reach 2.5 knots in spring tides (Stephens 1973; BPA 1994).

Noosa Council undertook beach replenishment works along the 800 m Noosa Spit foreshore in 1998 with sand dredged from sandbars just inside the estuary mouth. At the request of Queensland Fisheries Service, wide, intertidal sandy habitats were created along the foreshore using the dredge spoil, rather than creating non-tidal habitats behind a rock wall; the objective was to provide habitat suitable for colonisation by benthic invertebrates and to potentially offset the loss of fish-foraging habitat in the dredged area. Sand was pumped ashore and discharged directly against the existing eroded riverbank. A bulldozer was then used to create the design profiles. The new foreshore was constructed with an upper profile of MHWS (0.35 m AHD[Australian Height Datum]) and a toe at MLWS (–0.42 m AHD), physically resembling other sandy intertidal foreshores in the lower section of the Noosa River.

Several natural intertidal habitats within the FHA in the lower estuary were selected as reference sites (Fig. 1), since these habitats in the Noosa River are variable, especially for the presence of adjacent vegetation, degree of exposure to currents, sediment type, etc.

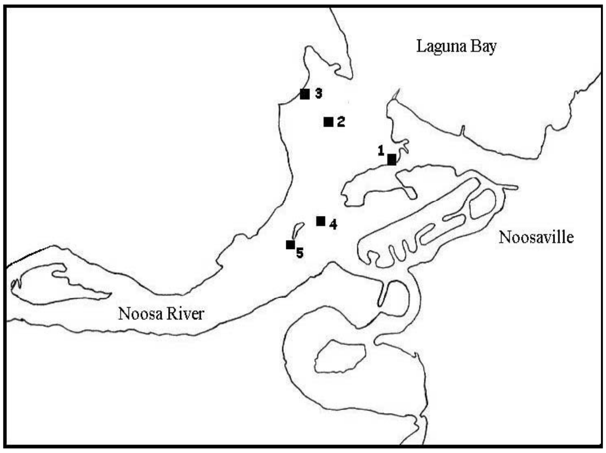

Fig. 1. Sampling regions, Noosa River estuary, Queensland, Australia.

Macro-infauna

Methods

Macrobenthic animals (important dietary items for fish) in the sediment were sampled at approximately 1 week, 1 month, 3 months, 5 months and 10 months after the completion of dredging. Data were also available from the reference and dredge areas prior to dredging (Skilleter unpublished). Samples for examination of macrobenthic fauna were collected with a 15 cm diameter core, pushed 15 cm into the substratum. The core was capped on top and sealed with a metal sheet underneath, then excavated without loss of sediment. Sediment cores were transferred to plastic containers and fixed with 2% formaldehyde and Rose Bengal stain. Macrobenthos was defined as all fauna retained on a 0.5 mm sieve.

Previous studies of soft sediments indicate a high degree of small-scale and large-scale patchiness (e.g. Morrisey *et al.* 1992a, 1992b: Thrush *et al.* 1997). Sampling therefore incorporated spatial variation at three spatial scales: among replicate Cores (<1 m apart), among Sites (tens of metres apart) and among Locations (hundreds of metres apart).

The most common macrobenthos were grouped in broad categories, 'prey groups', to assess fish feeding requirements within the habitat. Most benthic carnivores are relatively generalist feeders, and fish are more likely to target prey on the basis of size, general body morphology and accessibility rather than on the basis of species. The most common taxa of macrobenthos were arranged into 'prey groups' as follows: Amphipods, Brachyurans, Polychaetes and Bivalves. Data from Reference sites 3, 4 and 5 are presented here. December 1998 and January 1999 were excluded from this preliminary analysis since Reference site 3 was not sampled on those occasions.

Preliminary results and discussion

The abundance of benthic fauna in the habitats to be used as References was extremely variable over time AND SPATIALLY (Fig. 2), hence any comparisons between created habitat and natural areas will vary depending on which Reference site is being examined, AND WILL ALSO VARY ACCORDING TO THE MONTH SAMPLED. Multivariate analyses of the variation within Regions using the four 'prey groups' as variables revealed important differences at the spatial scale of Locations within Regions, particularly between Reference sites 5 and 3. These results highlight the importance of using multiple reference sites at multiple spatial scales to accommodate for the high degree of natural variability.

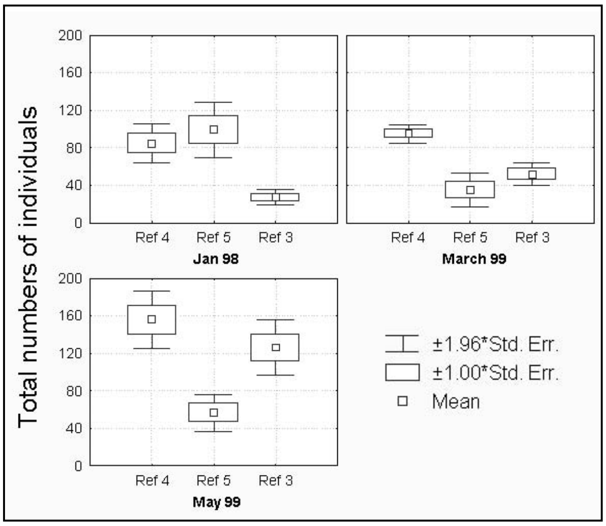

Fig. 2. Mean number of individuals per core from macrobenthic core samples taken at three Reference regions. A total of 16 cores per region were taken.

Sediment characteristics – in progress

Physical characteristics that may influence the spatial and temporal distributions of macrobenthic fauna were investigated by examining variations in physical measures such as sediment characteristics including grain size and sorting, and organic content. Samples for analysis of sediment granulometry and organic content were collected in 7 cm and 5 cm diameter cores respectively.

Nekton

Methods

Nekton sampling focussed on species that use unvegetated sandy sediments for feeding and protection, such as whiting *Sillago* sp., bream *Acanthopagrus australis*, tarwhine *Rhabdosargus sarba*, flathead *Platycephalus* sp., and flounder *Pleuronectus* sp. (e.g. Weng 1983; Quinn 1993; Hyland 1993). Specialist feeders are a stronger indicator of the specific foraging values of a habitat than more generalised feeders which exploit a wide range of habitat types. Generalist benthic feeders may also take prey items from the water column or make use of primary production (plant or detrital material). These alternative sources of food are less dependent upon the specific characteristics of the habitat and are likely to be available even in highly modified habitats. The study hypothesis is that the sediments of the Nourished region ('Nourish') will support secondary productivity in the form of benthic invertebrates *in addition to* more widely available marine food items.

Fish usage of the created and natural habitats was estimated by sampling fish in two sizes of diagonal-mesh beach-seine nets, having a line of floats attached to the top edge and lead weights attached to the base in order to keep the net vertical in the water column. Seine nets are used extensively on beaches and in estuaries to catch mullet, whiting, Australian salmon, tailor and bream (Kailola *et al.* 1993). The large seine net was 50 m long with a drop of 3 m and 10 mm mesh size. A small motor vessel was used to deploy this net in a circle, with one end anchored on shore. The net was then hauled up onto the beach. Two replicate hauls were taken per region. The small seine net was 10 m long with a 2 m drop and mesh size of 2 mm, targeting juvenile and smaller fish. This net was walked along the shallows parallel to the shoreline for a short distance with a person holding each end, then drawn up onto the beach. Four replicate hauls were taken per region. Samples were taken on rising tides when fish were able to move up into the shallow intertidal area. All fish caught were immediately placed on crushed ice, then frozen prior to identification to species level and measurement.

Detailed investigation of the influence of temporal scales on fish usage of habitats

Comparison of habitats must consider the fact that fish using the habitat vary in their patterns of use at several temporal scales, including season, phases of the moon and time of day. For many marine species, reproductive activity peaks around the full and new moons, which are associated with the highest spring tides each month (e.g. Blaber and Blaber 1980; Pollock and Weng 1983). Diurnal cycles are also known to be important in influencing fish distribution over short time scales. Many fish species are adapted for nocturnal activity due to the increased protection from visual predators. Fish assemblages using estuarine habitats are consequently often appreciably different between day and night (Rountree and Able 1993; Gray *et al.* 1998; Morrison *et al.* 2002). Seasonal cycles are likely to influence the timing of recruitment of juveniles into the estuary, so abundance of smaller size classes is expected to vary at this time scale. Two distinct periods of spawning have been identified for the majority of fishery species in south-eastern Queensland; a relatively discrete peak during winter and a longer period over summer (Hopkins and White 1998).

Our sampling design measured variation in the use of the created and natural habitats between seasons (spring/summer *v.* winter), within seasons (3 random months within each season), between lunar phases (full moon *v.* new moon) and between diurnal periods (day *v.* night). To our knowledge this study is the first project to take into account all these potential levels of temporal variation when comparing fish use of habitats.

Fish were analysed according to feeding guilds to assess directly the value of the habitat as a fish foraging area. Categorisation was based upon the dominant prey species targeted, although estuarine fish are fairly opportunistic and will also take other species besides the target groups. Review of the relevant literature and results of the pilot study (stomach contents analysis of fish of target species netted during the interim dredging situation in June 1998 between Preliminary and Main dredging) were used to categorise all species caught into feeding guilds.

Data from all Large net hauls taken over Winter 2001 are presented here. The Planktivorous guild was excluded from analysis of total numbers of individuals because this group were encountered only occasionally as very large schools.

Preliminary results and discussion

Fish abundance (Fig. 3) varied significantly between day and night, with much greater variation between the Nourish region and the Reference areas at night than during the day. This complicates the interpretation of any comparisons between created and natural habitats, and may indicate that the created region is used differently by nocturnally active fish than by diurnal fish.

Species diversity (Fig. 4) varied considerably at both the Nourish and Reference regions. There is no clear pattern in the diversity of fish using the created region compared to Reference regions, since the amount of variation between created and natural regions depends on the month and lunar phase in which sampling occurred.

Fish and squid caught during Winter 2001 were categorised into trophic guilds (Table 1). Piscivorous fish were caught only in very small numbers. Large schools of Planktivorous species were caught occasionally at the Nourish regions, with small numbers of individuals caught at the reference regions. Numbers of individuals within the target guild 'Benthic-invertebrate' carnivores (Fig. 5) varied among created and natural habitats according to lunar phase and whether fish were netted during the day or at night. For example, if sampling had been restricted to the new moon at night it might be concluded that numbers at the Nourish region were comparable with those at Reference regions, whereas if sampling occurred during the full moon the created site would be assessed as having low abundance compared with natural habitats.

Sampling at multiple temporal scales is clearly important in establishing a complete understanding of the way in which estuarine fish use the created habitat relative to the natural areas. Data obtained from this comprehensive sampling design will also suggest the times when estuarine habitats are of most importance, particularly for species that have discrete pulses of recruitment. Data from the small-net samples will provide information on the use of the site by juveniles and thus indicate the value of the created habitat as a nursery area.

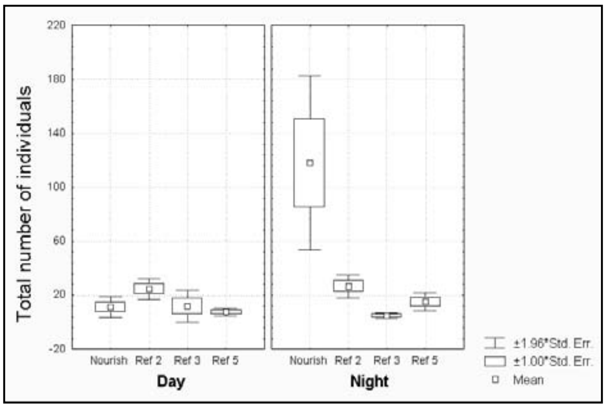

Fig. 3. Mean number of individuals per sample of fish from large-mesh seine samples, at three Reference regions and the artificial 'Nourish' region. A total of 12 seines per region were taken during each diurnal period over Winter 2001.

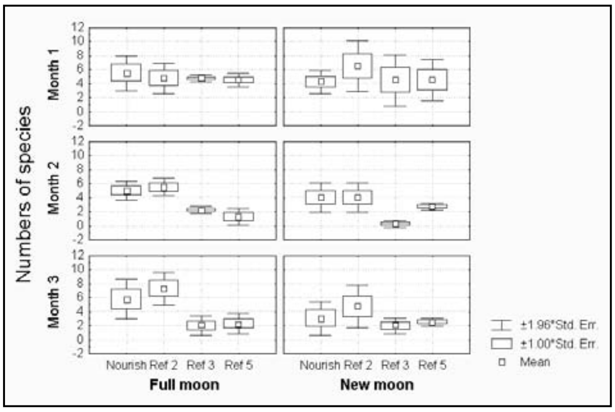

Fig. 4. Mean number of species of fish per sample from large-mesh seine samples, at three Reference regions and the artificial 'Nourish' region. A total of 4 seines per region were taken during each lunar period within each month over Winter 2001.

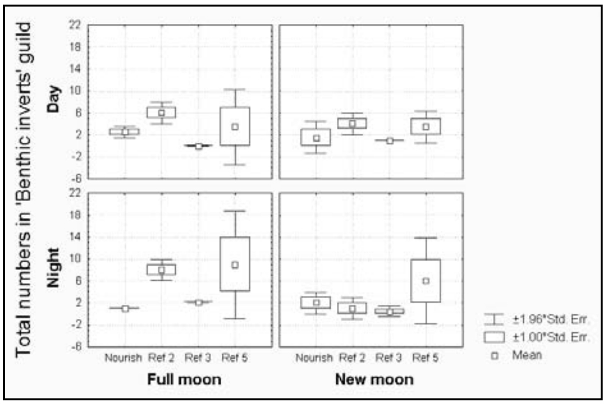

Fig. 5. Mean numbers per sample of fish from the 'benthic-inverts guild' from large-mesh seine samples, at three Reference regions and the artificial 'Nourish' region. The "benthic-inverts" guild contains fish classified on the basis of the literature and a pilot study as feeding on benthic invertebrates. A total of 6 seines per region were taken during each diurnal period within each lunar period over Winter 2001.

Fish dietary requirements - in progress

The range and types of invertebrate taxa that are being consumed by fish will be determined through analyses of the stomach contents of fish collected concurrently with sediment sampling. Samples were taken for analysis at intervals of approximately 1 week and 10 months after completion of dredging. Dietary requirements of the fish will be compared with data on the available prey species colonising the created banks. Where stomach contents are to be analysed, fish are transferred within 4 h to drums

Table 1. Categorisation of all fish and squid caught into trophic guilds (adult size classes only).

Trophic guild	**Family**	***Species name***	**Common name**
Benthic-algae/meiofauna	Kyphosidae	*Girella tricuspidata*	luderick
Benthic herbivores:	Monacanthidae	*Monacanthus chinensis*	fan-belly leatherjacket
algal scrapers, detritus, meiofauna	Mugilidae	*Liza argentea*	gold-gill mullet
		L. dussumieri	flat-tail mullet
		Mugil cephalus	sea mullet
		M. georgii	fantail mullet
		Valamugil seheli	blue-tailed mullet
	Penaidae	*Metapenaeus bennetti*	greasyback prawn
		M. macleayii	school prawn
		Penaeus esculentus	brown tiger prawn
	Siganidae	*Siganus spinus*	black spinefoot
	Hemiramphidae	*Hyporhamphus ardelio*	river garfish
Benthic-macroinvert	Bothidae	*Pseudorhombus arsius*	large-toothed flounder
Specialist benthic carnivores:	Dasyatidae	*Dasyatis fluvorum*	brown stingray
predominantly macro-	Gerreidae	*Gerres filamentosus*	threadfin silver belly
invertebrates		*G. subfasciata*	common silver belly
	Mullidae	*Upenaeus tragula*	bar-tailed goatfish
	Plotosidae	*Euristhmus lepturus*	long-tailed catfish eel
		Plotosus lineatus	striped catfish eel
	Rhinobatidae	*Aptychotrema rostrata*	common shovel-nosed ray
	Sillagidae	*Sillago ciliata*	summer whiting
		S. maculata	winter whiting
	Sparidae	*Acanthopagrus australis*	yellow finned bream
		Rhabdosargus sarba	tarwhine
Benthic-macroinvert/algae	Calappidae	*Matuta planipes*	ringed surf crab
Benthic scavengers / omnivores:	Mugilidae	*Mxyus elongatus*	tallegalane mullet
Macro-invertebrates and algae	Portunidae	*Portunas pelagicus*	blue swimmer crab
		Thalamita spp.	swimming crab
	Scatophagidae	*Scatophagus argus*	spotted scat
	Tetraodontidae	*Marilyna pleurostica*	banded toadfish
		Tetractenos hamiltoni	common toadfish
		Torquigener perlevis	spineless toadfish
		T. pleurogramma	weeping toadfish
		T. squamicauda	brush-tail toadfish
Benthic-macroinvert/pisciv	Platycephalidae	*Platycephalus arenarius*	flag-tailed flathead
Generalised benthic carnivores:		*P. caeruleopunctatus*	blue-spotted flathead
Macro-invertebrates and fish		*P. endrachtensis*	flathead
		P. fuscus	dusky flathead
		P. indicus	bar-tailed flathead
		P. sp. 1.	flathead sp 1.
Benthic-pisciv	Scorpaenidae	*Centropogon mamoratus*	fortesque
Benthic piscivores	Synodontidae	*Saurida gracilis*	slender grinner /lizardfish
	Uranoscopidae	*Ichthyscopus lebeck sannio*	northern stargazer
Water column-pisciv	Carangidae	*Scomberoides lysan*	queenfish
Pelagic piscivores	Fistularidae	*Fistularia commersoni*	smooth flutemouth
(feed in water column)	Lutjanidae	*Lutjanus russelli*	moses perch
	Pomatomidae	*Pomatomus saltatrix*	tailor
	Sphyraenidae	*Sphyraena obtusata*	yellow-tailed sea pike
	Idiosepiidae	*Idiosepius pygmaeus*	pygmy squid
	Leiognathidae	*Leiognathus fasciatus*	black-tipped ponyfish
Water column-planktoniv	Ambassidae	*Ambassis marianus*	glass perchlet
Pelagic planktivores	Atherinidae	*Atherinomorus ogilbyi*	common hardyhead
(feed in water column)	Clupeidae	*Herklotsichthys castelnaui*	southern herring

of ethanol. Larger fish are injected with ethanol directly into the gastrointestinal tract prior to immersion. Total numbers of prey items and estimate of percentage volume are recorded. The analyses should provide information on the contribution of different groups of macrobenthic prey to the diet of estuarine fish at different stages of the life cycle.

Experimental comparison of fish growth rates – in progress

Fish growth and survival in created and natural habitats will be measured by manipulative experiments examining the growth rates of juvenile fish for species that forage in these areas. Experimental enclosures will be used to constrain fish to forage in different areas of habitat (created areas *v.* reference areas) and the growth and survivorship of the fish will be measured after a fixed period of time. Enclosures will be elongated and positioned so that part of the cage includes a subtidal area, allowing the fish to retreat as the tidal level falls. This approach has been successfully used elsewhere to examine differences in habitat value for fish foraging in intertidal areas (Irlandi and Crawford 1997).

These experiments will test how much condition fish could gain from the habitat if they forage there, which can then be linked to the data on actual fish use of the habitat.

CONCLUSIONS

In order to assess the value of a created site as a fish foraging habitat, a comprehensive approach to measurement of habitat functions is required. Multiple components must be examined and linked together rather than assessing single components in isolation. A trophic-based approach is useful for analysing faunal presence as a direct assessment of the ability of a potential foraging habitat to support fauna. Preliminary results from our investigation underline the high degree of natural variability that is present in estuarine systems, and the importance of considering multiple spatial and temporal scales to address this variability and to gain an understanding of how the different habitats are used by fauna at different times.

A valid system of assessing habitat performance has clear importance for the declaration and management of APAs. APAs are declared to protect valuable habitat features from anthropogenic impacts. Where unresolvable conflict arises between conservation objectives and developmental pressures, economic arguments frequently prevail. Such conflicts can often lead to removal or reduction of the legislative protection for an area. For this reason it is of paramount importance that the selection of areas for inclusion into APAs be based upon valid, defensible criteria that can be used to counter arguments based primarily on economic values. An important criterion if an APA is to achieve biodiversity, conservation and productivity objectives is ability of the habitat to support fauna. If APAs are chosen to protect and enhance desired habitat functions, it is necessary to be able to measure those habitat functions. An over-simplistic approach to measures of habitat performance in complex estuarine systems may lead to misleading conclusions. An integrated approach is more useful in measuring ecological functions and assessing habitat value.

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Do Estuarine No-Take Reserves Affect the Abundance and Length Frequencies of Fishery Target Species – An Assessment of Two North Queensland Estuarine 'No-Take' Marine Park Zones

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Abstract

Fish traps, crab pots and baited drift lines were used to compare abundance and length–frequency distributions of fish and crab target species between no-take reserves (NTR) and adjacent areas open to fishing in the Daintree and Moresby Rivers of north-eastern Australia. Tide speed and wind direction limited the effectiveness of baited drift lines. Catch rates in the fish traps were so low that only overall fish captured (total fish), pikey bream, *Acanthopagrus berda*, and mud crabs, *Scylla serrata,* were sufficiently abundant for analysis of abundance. Of those taxa, only male *S. serrata* in the Daintree River and female *S. serrata* in the Moresby River showed any significant differences between zones. In both cases relative abundance was higher in the open zone. Those differences were not found in crab pot samples where male *S. serrata* in the Moresby River were significantly more abundant in the NTR. In terms of length frequency, greater proportions of larger *A. berda* and male *S. serrata* were captured in the Moresby NTR than outside. All non-significant results exhibited low power due to high variability and low catch rates. Although circumstantial without pre-closure data, results indicate that NTRs may lead to larger average sizes and higher abundances of male *S. serrata* in the Moresby River.

Keywords: marine protected areas, no-take reserves, *Scylla serrata*, *Acanthopagrus berda*, estuaries

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Introduction

Since the publication by Beverton and Holt (1957), most fishery management strategies have been designed to reduce the likelihood of both recruitment overfishing and growth overfishing by reducing fishing effort and/or limiting allowable catch (Dugan and Davis 1993; Bohnsack 2000). Beverton and Holt (1957) also identified spatial refuges as a potential management tool although these have been largely overlooked (Bohnsack 2000). In contrast to traditional methods generally developed for single-species stocks, permanent spatial refuges or no-take reserves (NTRs) embody a more holistic, ecosystem-based approach to resource management (Bohnsack 1998; St Mary *et al.* 2000). Thus, the NTR approach is particularly pertinent for complex multi-species fisheries resources, such as those found in the nearshore waters of tropical Queensland.

A spatial refuge, or NTR, refers to a portion of habitats that is totally protected from all forms of extractive use (Alcala 1988). In the past, many fisheries were probably afforded similar protection due to remoteness and inaccessibility. However, advances in technology have virtually eliminated those natural sanctuaries (Bohnsack 1998). NTRs can provide similar refuges, so these have recently been advocated as providing a cost-effective strategy to sustain fish stocks (e.g. Plan Development Team 1990; Dugan and Davis 1993; Russ and Alcala 1996a; Ballantine 1997; Ward *et al.* 2000). Higher abundances and larger sizes of fishery target species have been reported in NTRs created for a variety of reasons and in a diversity of habitats (Dugan and Davis 1993; Bohnsack 1998, 2000; Dayton *et al.* 2000; Roberts 2000; Ward *et al.* 2000). According to Dugan and Davis (1993), increases in abundance are presumably due to decreased fishing mortality, by-catch and disturbance, which over time are likely to lead to increased longevity and larger sizes within target species.

Despite being among the most modified and threatened of aquatic habitats, estuaries and associated coastal waters have been shown to support many essential fisheries (Blaber *et al.* 2000). The only published study of the effects of an estuarine NTR on fish stocks was that of Johnson *et al.* (1999) in the Indian River, Florida. They reported significantly greater relative abundances and larger size classes of fishery target species within the bounds of the estuarine NTR than in adjacent fished areas. However, because of the absence of pre-closure data, the lack of replicate NTRs and the heavily modified system, the results of Johnson *et al.* (1999) do not necessarily mean that the Indian River estuarine NTR enhanced fish stocks within its bounds. Differences in fish stocks between the NTR and adjacent areas in the Indian River may reflect environmental differences rather than a beneficial effect of the NTR.

Effective testing of the effects of estuarine NTRs is hampered by the small number of estuarine NTRs available, the scarcity of adequate long-term data, high natural variability, a lack of appropriate control areas, inadequate enforcement of fisheries legislation, and insufficient research resources (McClanahan and Kaunda-Arara 1995; Dayton *et al.* 2000).

Tropical Queensland estuaries are highly diverse and of considerable importance to fisheries within their bounds and as habitats to certain life stages of target species caught outside estuaries (Robertson and Duke 1987; Blaber *et al.* 1989; Thorrold 1993; Sheaves 1995; Thorrold and McKinnon 1995). The presence of two established NTRs (zoned marine national parks) in the estuarine reaches of the relatively unmodified Daintree and Moresby River systems in tropical north Queensland provided a rare opportunity to assess the effectiveness of estuarine NTRs as a fisheries management tool. This study aimed to determine whether the relative size and abundance of fish and crab species targeted by anglers were greater in those two estuarine NTRs than in adjacent fished areas.

MATERIALS AND METHODS

Study areas

This study was conducted in the mangrove-lined estuarine reaches of the Daintree River (16°17'S, 145°24'E) and Moresby River (17°39'S. 146°05'E), on the wet tropical coast of north-eastern Australia. A section of the south arm of each estuary was zoned marine national park (equivalent to an NTR) in 1989. Those areas were selected for their relatively undisturbed wetlands and good assemblages of mangroves. In estuarine areas adjacent to the NTRs, a restricted number of commercial fishers use mesh nets to target species such as barramundi (*Lates calcarifer*), blue salmon (*Eleutheronema tetradactylum*), king salmon (*Polydactylus sheridani*), grunter (*Pomadasys kaakan*), pikey bream (*Acanthopagrus berda*) and sea mullet (*Mugil cephalus*) (Russell *et al.* 1998). Commercial and recreational harvesting of mud crabs (*Scylla serrata*) also occurs in adjacent areas where recreational fishers also use lures and baited hooks to target a wide range of fish species (Kailola *et al.* 1993; Russell *et al.* 1996, 1998).

Sampling methods

Fish traps

Fish traps were employed as the primary sampling method because the use of gill nets was prohibited by Queensland Parks and Wildlife Service. Visual census was not possible because of high turbidity, and seine netting was not feasible because of the steep, muddy banks and the presence of salt-water crocodiles (*Crocodylus porosus*). Traps in this study were based on a 'D-design' (the D laid on its side) commonly used by commercial fishers in Australian estuaries (Mark Miller, commercial fisher, *pers. comm.*).

Sampling was conducted for ten 24 h periods in the Daintree from 29 June to 12 July 2001 and in the Moresby from 16 to 26 July 2001. To reduce extraneous sources of variation, in each sampling period ten 'paired' sites (one NTR, one open) were sampled simultaneously, with traps set and retrieved on the daytime high tide. Sites were paired on the basis of habitat similarities and high-tide bottom measurements of temperature (°C), salinity (‰) and dissolved oxygen (mg/L). Owing to the limitations imposed by NTR size (~4 km), sites were allocated a bank distance of approximately 300 m. Within each site, areas of high structural heterogeneity, such as snags and deep holes, were identified and traps randomly distributed amongst these. Trap size and available boat-space restricted trap numbers and movement, therefore site allocation was made progressively along each zone.

In each site, one large trap and two small traps were used. Small traps (900 mm long, 720 mm high and 800 mm wide) were covered by 12 mm galvanised hexagonal bird wire with entrance funnels at each end tapering to an inner opening 120 mm high by 60 mm wide. Large traps (1400 mm long, 900 mm high and 1100 mm wide) were enclosed by 50 mm galvanised hexagonal chicken wire with the two entrance funnels tapering to 200 mm by 100 mm. Each trap was baited with pilchards, prawn heads and bread. Fish captured were identified to species, measured for total length (TL ± 2 mm), and released at the site of capture. The sex of captured mud crabs was recorded, carapace width measured (CW ± 2 mm) and the terminal segment (dactylus) of one of the last pair of walking legs (pereiopods) removed to enable identification of recaptured individuals. These 'tipped' crabs were excluded from analyses of abundance.

Crab pots

Crab pots were of a cylindrical collapsible design commonly employed by commercial mud-crab fishermen (Kailola et al. 1993). When erected, 50 mm mesh is stretched over the steel frame 270 mm high and 780 mm in diameter, with two horizontal tapered entrance funnels set opposite one another in the trap sides. An equivalent number of traps was simultaneously set in the NTR and open zones for six daylight hours on two sampling occasions in each estuary. Over the two sampling periods a total of 52 crab pots were set in each zone of the Daintree River (104 in total) and 47 in each zone of the Moresby River (94 in total). Traps were baited with one whole mullet. Individual crab pots were considered replicates and apart from the minimum-distance criterion of 100 m (Williams and Hill 1982) were allocated randomly throughout the respective zones for each sampling period. Again, captured crabs were sexed, tipped and released.

Baited lines

To census larger predatory species, hook and lining has been found to be an acceptable method (Sutherland 1996). To eliminate the 'fishing experience/ability' bias, five baited hooks were set afloat (one hook per float) in a line perpendicular to the bank and allowed to drift. Each set of five was released in the NTR and open zones simultaneously. However, after numerous attempts this method was discontinued because catch rates were low.

Data Analysis

Abundance

With only two NTR zones to compare, pseudo-replication complications were avoided by analysing each estuary separately. Catch rates were low with no fish of particular species being trapped in a number of Zone × Trap combinations, thus only overall fish captured (total fish), pikey bream (*Acanthopagrus berda)*, and male, female and total mud crabs (*Scylla serrata*) were analysed. Results for total crabs mirrored those of the males and are therefore not reported. To obtain a distribution of residuals that showed little evidence of heterogeneity and markedly corrected normal probability plots, the following transformations were required; total fish, pikey bream and Daintree female crabs by $\log_{10}(x + 0.5)$, Moresby female crabs by $x^{½}$ and male crabs by $(x + 0.5)^{½}$. Crab pot data were analysed by one-way ANOVAs comparing mean numbers of *S. serrata* (male and female) captured per crab pot in each zone. To account for more of the variability among the fish trap data, blocked factorial ANOVAs with factors 'zone' (open/NTR), 'trap' (large/small) and the blocked factor 'site' were used to compare the equality of mean numbers of fish or crabs per trapping period in each zone.

The data for even the most common species acted like discrete variables and contained little quantitative information. A presence/absence logistic analysis was therefore also conducted in each zone/fish-trap combination. Non-significant results occurred if the ratio of presence/open ≈ the ratio of presence/absence closed. Again, total fish, *A. berda*, and *S. serrata,* males and females, were analysed. However higher catches in the Moresby also allowed the inclusion of *Lutjanus russelli*, *Epinephelus coioides* and *E. malabaricus.*

Length distributions

The length distributions of pikey bream, crabs of both sexes, *L. russelli*, *E. coioides* and *E. malabaricus* captured by all methods in the NTR and open zones of each estuary were compared by Kolmogorov–Smirnov tests.

RESULTS

Total Catch

In total, 596 mud crabs and 234 fish, consisting of 16 species from 10 families (Table 1), were collected by the three methods.

Crab catches were dominated by males (70%). *Acanthopagrus berda* represented almost half (46.8%) of the total fish catch, and *Lutjanus russelli*, *Epinephelus coioides* and *E. malabaricus* were also prevalent, with those four species combined constituting 80.2% of total fish numbers. Fish and crab numbers were higher in the Moresby River constituting 60.7% and 72.9% of total catch (both rivers combined) respectively. However, there was little difference in the number of species between the two estuaries and between zones within an estuary. Tide speed and wind direction limited the effectiveness of baited drift lines therefore captures by this method accounted for only 4.7% of fish captured and could not be analysed. The number of species captured in each estuary was only a small proportion of those recorded by Russell *et al.* (1996, 1998).

Environmental conditions

Bottom salinity, temperature and DO measurements were similar between paired sites. However, none were significantly correlated with catch rates.

Table 1. Total numbers and composition of fish and crab catches per zone of the Daintree and Moresby Rivers. Species commonly targeted by commercial and/or recreational anglers are denoted (*), number of fish species are in parenthesis.

Species	Common Name	Daintree River		Moresby River		% of
		open	closed	open	closed	Total
FISH		**(10)**	**(8)**	**(9)**	**(8)**	
Ariidae						
Arius armiger	Threadfin catfish	0	1	0	0	0.4
A. graffei	Blue catfish	3	5	1	4	5.6
A. thalassinus	Giant catfish	2	2	0	0	1.7
Batrachoididae						
Halophryne diemensis	Banded frogfish	0	0	1	0	0.4
Haemulidae						
*Pomadasys kaakan**	Barred grunter	1	0	0	0	0.4
Lutjanidae						
*Lutjanus argentimaculatus**	Mangrove jack	0	1	2	0	1.3
*L. johnii**	Fingermark seaperch	1	0	0	0	0.4
*L. russelli**	Moses perch	7	1	20	8	15.4
Monodactylidae						
Monodactylus argenteus	Butterbream	5	0	1	1	3
Pomacentrinae						
Neopomacentrus cyanomos	Violet damselfish	10	0	0	2	5.2
Serranidae						
*Epinephelus coioides**	Estuary cod	1	2	5	13	9
*E. malabaricus**	Morgan's cod	0	2	3	16	9
Sparidae						
*Acanthopagrus berda**	Pikey bream	24	23	38	24	46.8
*A. australis**	Yellowfin bream	0	0	1	1	0.8
Gobidae						
Glossogobius biocellatus	Sleepy goby	1	0	0	0	0.4
Total Fish (15 species)		55	37	72	70	
CRUSTACEANS						
Scylla serrata (male)*	Mud crab	74	50	110	183	70.0
S. serrata (female)	Mud crab	19	18	107	35	30.0
Total Crabs (1 species)		93	68	217	218	

Table 2. Blocked factorial ANOVA for the Daintree and Moresby Rivers testing for differences in numbers of total fish, pikey bream (*Acanthopagrus berda*), and mud crabs (*Scylla serrata*) captured using two trap sizes (small and large) across two management zones (NTR and open). The random factor 'site' was used as a block. Results for each River considered separately. F ratios significant at $P \leq 0.05$ are in bold. [1]: power ≤ 0.05, [2]:0.05< power ≤ 0.30, [3]: 0.30 < power ≤ 0.50, the remainder power > 0.50.

	Number of individuals							
Source of variation	Fish (total)		Pikey bream		Crab (male)		Crab (female)	
and sites	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Zone (NTR/open)								
Daintree River	2.130	0.151[2]	0.089	0.767[1]	**13.695**	**0.001**	0.849	0.362[1]
Moresby River	0.111	0.740[1]	0.563	0.457[2]	3.006	0.090[3]	**25.483**	**<0.001**
Trap (large/small)								
Daintree River	2.271	0.139[2]	0.958	0.333[2]	0.303	0.584[1]	0.895	0.349[1]
Moresby River	3.858	0.056[3]	1.556	0.219[2]	1.180	0.283[2]	1.168	0.286[2]
Site (1-10)								
Daintree River	3.442	0.003	1.562	0.156[3]	1.742	0.107[3]	0.891	0.541[2]
Moresby River	0.672	0.730[2]	0.404	0.926[2]	2.456	0.023	1.711	0.116
Zone × Trap								
Daintree River	0.275	0.603[1]	0.040	0.842[1]	0.120	0.731[1]	0.250	0.620[1]
Moresby River	0.577	0.451[2]	2.557	0.117[3]	0.244	0.624[2]	1.045	0.312[2]

Relative Abundance

Fish traps

Of the variables studied, only the factor of management zone (NTR/open) for Daintree male crabs and Moresby female crabs showed any significant differences (Table 2). In both instances, catches were higher in the open zones (Figs 1a and 1d).

The effect of fish-trap size was not significant for any variable, and no main effects were modified by interactions with other factors. The factor 'zone' variance ratio (*F*) is much lower than 1 for Moresby River total fish (0.111) and Daintree River *Acanthopagrus berda* (0.089); this indicates that the error variance is greater than natural variation. This high variation resulted from extremely high catch numbers – double and treble the mean- – in one or two traps in each estuary. In general, the very low numbers of fish captured resulted in clumped (more discrete) dependent variables, rather than continuous. Even for the most common fish species captured (*A. berda*), the highest average number of fish per trap was 1.17 (Moresby River small trap).

The presence/absence logistic analysis revealed results consistent with the factorial ANOVA in that there were significant effects of zone (Table 3) for Daintree male *S. serrata* and Moresby female *S. serrata* with both higher in the open zone. Significant interactions between trap and zone were found for Moresby River *A. berda* and *E. coioides.* Results for *E. coioides* and *E. malabaricus* in the Moresby River show that zone is not independently important for these species, although zone was significant for *L. russelli* at the 0.05 significance level.

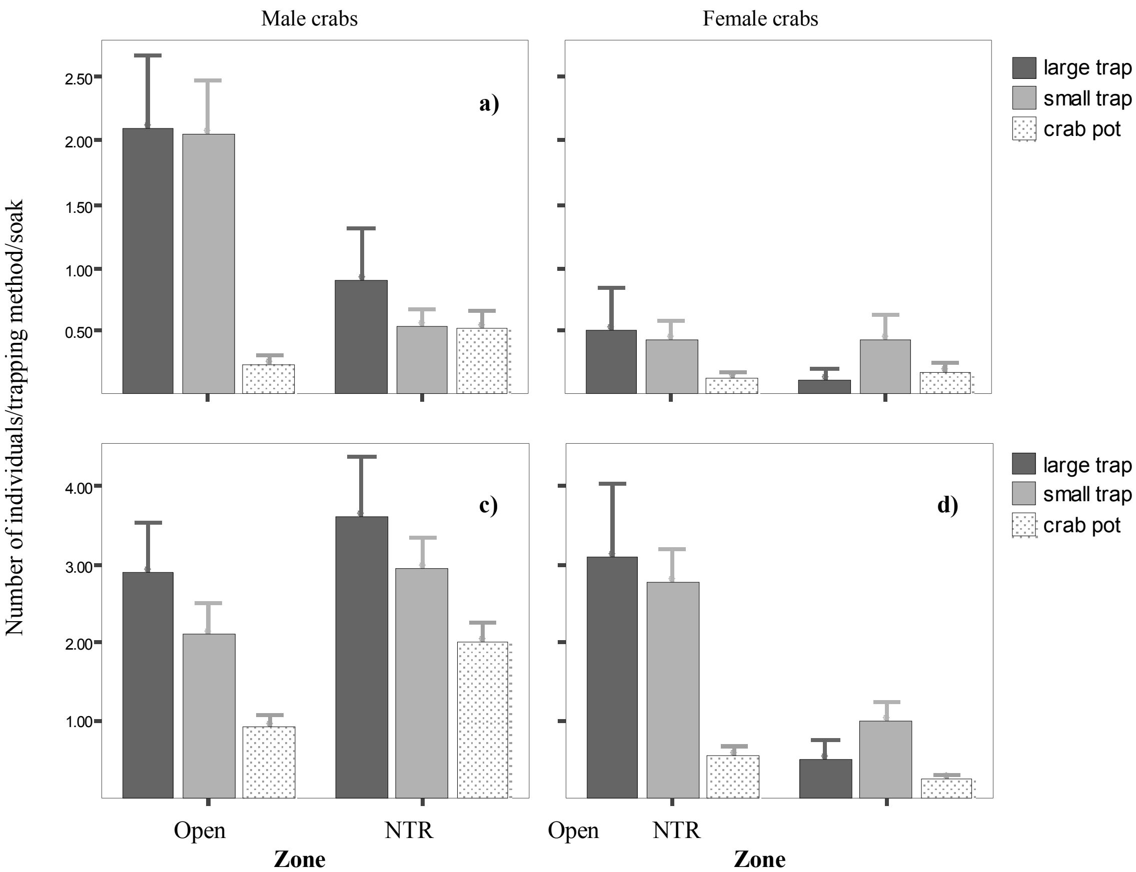

Fig. 1. Mean abundance (+1SE) for *Scylla serrata* captured in small and large fish traps and in crab pots within the two management zones; a) Daintree males, b) Daintree females, c) Moresby males, d) Moresby females. Untransformed data are displayed. Soak times for traps; 24 hours, soak times for crab pots; 6 daylight hours. Although fish traps and crab pots were analysed separately, graphical results are combined for ease of reference.

Table 3. Backward elimination of logistic models for presence/absence data for the four most common group/species/sex caught by fish traps in the NTR and equivalent open zones of the Daintree and Moresby Rivers, with the addition of *Epinephelus coioides*, *E. malabaricus* and *Lutjanus russelli* in the Moresby River. Significant results are denoted by asterisks; $P < 0.01$ (**), $P < 0.05$ (*).

Model	Total Fish	*Acanthopagrus berda*	*S. serrata* (male)	*S. serrata* (female)	*Epinephelus coioides*	*E. malabaricus*	*Lutjanus russelli*
Daintree River							
Trap * Zone	NS	NS	NS	NS			
Trap	*	NS	NS	NS			
Zone	NS	NS	*	NS			
Moresby River							
Trap * Zone	NS	*	NS	NS	*	NS	NS
Trap	NS	NS	NS	NS	NS	NS	**
Zone	NS	NS	NS	**	NS	NS	*

Table 4. One-way ANOVA comparing crab pot catches of Scylla serrata in NTR and open zones of the Daintree and Moresby Rivers. Results for each River considered separately. F ratios significant at the 0.05 level are in bold. 1: power ≤ 0.05, 2:0.05< power ≤ 0.30, 3: 0.30 < power ≤ 0.50, the remainder power > 0.50.

Source of variation and sites	df	Number of individuals			
		Crab (male)		Crab (female)	
		F	*P*	*F*	*P*
Zone (NTR/open)					
Daintree River	102	3.357	0.070[3]	0.293	0.590[1]
Moresby River	94	**13.004**	**0.001**	3.184	0.078[3]

Table 5. Probability values for Kolmogorov-Smirnov continuous data goodness of fit tests comparing the length distributions of the most common species between estuaries and management zones. Significant probabilities are in bold. Species where too few individuals were caught for comparison are shown as (-). The superscript (N) specifies that a greater proportion of larger individuals were caught in the NTR zone. Bracketed numbers in italics represent the number of individuals used in the analysis.

Species	Daintree open vs NTR	Moresby open vs NTR
Crustaceans		
Scylla serrata (male)	0.497 (124)	<0.001[N](293)
S. serrata (female)	0.259 (37)	0.780 (142)
Teleosts		
Acanthopagrus berda	0.384 (47)	0.009[N] (62)
Lutjanus russelli	-	0.320 (28)
Epinephelus coioides	-	0.425 (18)
E. malabaricus	-	0.983 (19)

Crab pots

The only result from crab pots (Table 4) that is in agreement with crab catches in fish traps (Table 2) was for Daintree female crabs (Fig. 1b), which showed no significant difference by either method. Accordingly, Moresby crab-pot captures of male crabs were the only significant result consistent with the hypothesis that relative abundance of target species would be greater in the NTR zone. Overall, the mean number of crabs per pot was very low compared with trap means; this is probably a reflection of the shorter soak duration, which did not include the hours of darkness when these crabs are most active (Hyland *et al.* 1984).

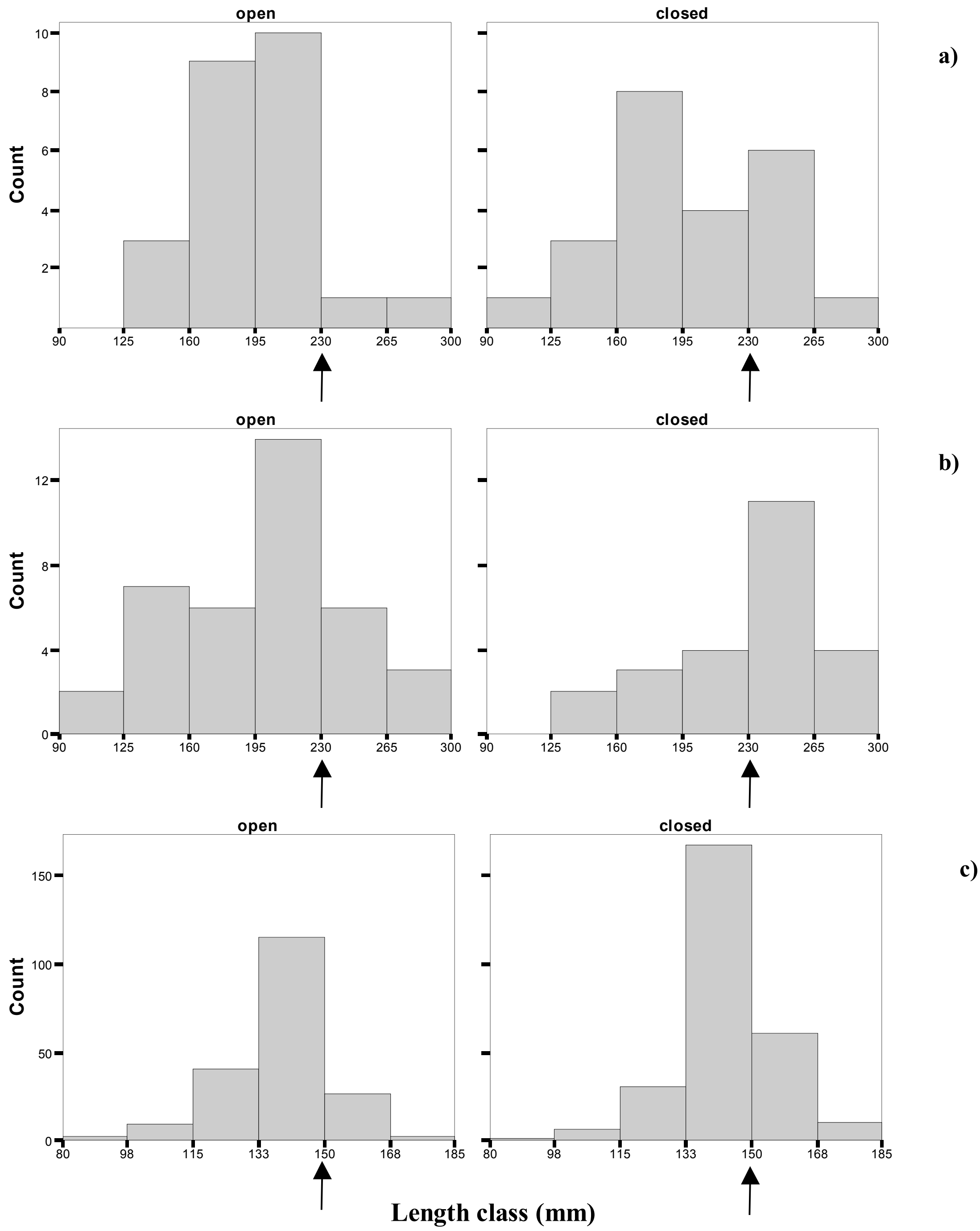

Fig. 2. Differences in length distributions between the NTR and open zones for a) *Acanthopagrus berda* in the Moresby River, b) *A. berda* in the Daintree River and c) *Scylla serrata* (male) in the Moresby River. Arrows indicate the minimum legal size.

Comparisons of length distributions

The length distributions of *Acanthopagrus berda* (Fig. 2a) and male *S. serrata* (Fig. 2c) in the Moresby River showed significant differences between zones (Table 5). In both cases there was a higher proportion of larger individuals captured in the Moresby NTR. In the Moresby River, 17.6% of male *S. serrata* captured in the NTR (Fig. 2c) were equal to or larger than the legal allowable carapace width of 150 mm (per Queensland Fisheries Regulations) compared with only 5.4% of those captured in the open zone. In the Daintree, percentages depicted an opposing trend, 5% in the NTR and 9.3% in the open. For *A. berda* captured in the Moresby NTR and open zones, 24.2% and 14.6% (Fig. 2a), respectively, exceeded legal size (230 mm); in the Daintree NTR and open zones, 14.9% and 4.23% (Fig. 2b) exceeded this size.

DISCUSSION

This is the first study that has attempted to evaluate differences in abundance and length distributions of selected estuarine target species between NTR and adjacent fished zones in Australia. It is also the first assessment of the variability within and between the two management zones using non-destructive trap and pot fishing methods.

Comparisons of abundance

With the exception of Moresby male *Scylla serrata* captured in crab pots, the results did not support the hypothesis that relative abundances of target species would be higher in the NTR zones than in adjacent fished areas. Indeed, presence/absence data and ANOVAs of fish trap catches for Daintree male *S. serrata* and Moresby female *S. serrata* showed greater abundances in the open zone. *S. serrata* adults are relatively sedentary (except for gravid females) whereas the larvae are dispersed widely (Hyland *et al.* 1984). This may result in situations where some localities become natural 'sources' and others natural 'sinks' (Conover *et al.* 2000). Although this study used a sampling design involving spatial comparisons at one time in an attempt to minimise sampling biases, comparisons are confounded if relevant intrinsic differences exist independent of the effects of NTR protection (Russ and Alcala 1996a). Conversations with Daintree River fishers revealed that the area now zoned the Daintree NTR had historically low catches for fish and crabs. In the absence of pre-closure data, the possibility that the Daintree NTR is an area where fish and crab abundances are normally low cannot be verified.

Local fishers in the Moresby River did not express such unequivocal opinions regarding pre-existing differences in fish distributions. High recreational and commercial fishing pressure on male *S. serrata* in fished areas of the Moresby (Russell *et al.* 1996) and limited movement of the males (Hyland *et al.* 1984) led us to speculate that the higher abundances of males captured in NTR crab pots may be due in part to the reduction in fishing effort there. Owing to higher variability in the data, males were not significantly more abundant in fish trap samples (P = 0.090), although they exhibited the same trend (Fig. 1c). Presence/absence fish trap data also showed significantly higher frequencies of occurrence of male *S. serrata* in the Moresby NTR (P<0.01).

Unlike male crabs, who are reported to move little (Hyland *et al.* 1994), berried females move offshore to spawn (Heasman 1980; Kailola *et al.* 1993). In the Moresby River, two berried females were captured in the open zone, and on three occasions female crabs in fish traps and crab pots were found to be covered by a large male. As the open zone is a direct path to the river mouth, the possibility exists that the significantly larger numbers of females in the Moresby open zone (Fig. 1d) may have been due to the beginning of a spawning migration to offshore areas. In addition, Williams and Hill (1982) report that *S. serrata* displays agonistic behaviour towards conspecifics and that such encounters reduce entry of further crabs to a trap or pot. This differential vulnerability to capture and number of large males in the Moresby NTR may have excluded entry of female crabs because they have smaller chelipeds than males (Keenan *et al.* 1998). This antagonistic behaviour toward smaller individuals was supported by observations in the Moresby NTR zone, where smaller crabs often had cracked or missing chelipeds when captured in traps with larger males.

Several submerged unmarked crab pots were discovered in the Moresby NTR zone during the study, providing proof of illegal crabbing. Similar evidence was not discovered in the Daintree. However, local residents suspected some level of poaching. In addition, tourists may have unwittingly fished these areas, since staff at the Daintree Tourist Information Centre were unaware of the existence of the NTR, and the signs denoting the NTR boundary were partially obscured by mangroves. As a relatively small amount of poaching can erode the benefits of NTRs (Jennings and Polunin 1996; Russ and Alcala 1996b; Pitcher *et al.* 2000; Ward *et al.* 2000), more adequate education and enforcement may result in more substantial benefits for fisheries resources in both estuaries.

The conclusion of Johnson *et al.* (1999) that NTRs showed greater abundance and larger size classes of exploitable species than did fished areas was based on 23,169 fish captured in trammel nets. In contrast, this study was based on 206 fish and the few species abundant enough to permit statistical analysis generated non-significant results that exhibited low power (Table 2). Thus, the probability of failing to detect any inter-zone differences was in most cases, very high. Nevertheless, it would be remiss to simply ignore non-significant results demonstrating low power by arguing that the null hypothesis would have been rejected had additional samples been taken (Fairweather 1991). For although no significant differences between zones were found for total fish and *A. berda* from either estuary (Table 2), the spatial distribution of fishes within estuaries is linked to a wide range of interacting factors e.g.

food availability, habitat preferences, and physical parameters (Robertson and Duke 1987; Sheaves 1992). *F* values less than one in all but Daintree total fish suggest that a large amount of unexplained variability was unaccounted for by the ANOVA model.

The beneficial effect of NTRs on fish abundance may also have been confounded by trap selectivity biased toward open areas. In both estuaries, snags were much less common in open areas; therefore each snag may have been inhabited by greater numbers of those species using this habitat preferentially (Sheaves 1992). In addition, the capture radius of fish traps and crab pots is known to vary with a number of factors such as prevailing currents, activity levels of the target species and attractiveness of the bait (Gunderson 1993). As the majority of open sites were located in the main river, the more constant flow provided by the larger catchment area, especially in the Daintree, may have increased the trap capture radius when compared to those in the NTR.

As reserves affect each species differently (Roberts 2000), non-significant differences in total fish may not be a reliable indicator of reserve effect as high numbers of one species in the NTR may have been counteracted by high numbers of another in the open zone. Changes in a particular species abundance is also likely to change with season, year, moon phase, etc. Sheaves (1996b) found that June and July were the worst months for trap catches in the two estuaries, therefore trapping in summer is likely to improve catch rates. Even so, other than *A. berda*, the fish species primarily targeted by fishers (barramundi, blue salmon, king salmon, grunter, and sea mullet) (Kailola *et al.* 1993; Russell *et al.* 1998) are not vulnerable to capture by traps (Sheaves 1992, 1993, 1995, 1996a, 1996b, 1998; Sheaves *et al.* 1999) and therefore are rarely recorded.

Comparisons of length distributions

A higher proportion of larger male *S. serrata* in the Moresby NTR (Fig. 2c) provides some support for the hypothesis that reduced fishing effort in the NTR has affected the length frequency of males of this species. A higher proportion of larger *A. berda* were also captured in the Moresby NTR zone with only two individuals exceeding legal size captured in the open zone (Fig. 2a). Although the length distributions for Daintree *A. berda* were not significantly different between zones, more individuals of legal size were captured in the NTR zone (Fig. 2b). The similar trend for both estuaries suggests that reduced fishing effort in the NTR zone may have also affected the length frequency of this species. These apparent effects may have also been due to other factors (such as pre-existing differences or different environmental conditions).

The lack of significant differences in the length distributions of larger predatory fish *E. coioides*, *E. malabaricus* and *L. russelli* may be because larger individuals of these species move offshore when reproductively mature (Sheaves 1995). The maximum sizes trapped were similar to those obtained by Sheaves (1995) who found that larger individuals were not captured by line anglers. Thus, it seems likely that the maximum sizes trapped reflect the maximum sizes of these fish present in the estuaries, regardless of zone.

CONCLUSION

With the exception of *A. berda* and one individual of grunter (*Pomadasys kaakan*), no other fish species primarily targeted by commercial fishers were captured by these methods. In addition, trap capture efficiency may have varied considerably between zones, confounding results and increasing variability estimates. This study found no consistent effect of NTRs on the size and abundance of *Scylla serrata* or any species of fish common enough for analysis, although low winter catch rates and high variability of the few species captured restricted the statistical power and reduced the probability of detecting any existing differences. The results of this study have highlighted the need to carefully consider whether these methods are appropriate for a general census of target fish species populations in the Daintree and Moresby river estuaries. However, they may be effective if the only target species of interest is *Scylla serrata.*

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THE ROLE OF AQUATIC PROTECTED AREAS IN THE AQUATIC ECOSYSTEM

Theme 5

KEYNOTE PRESENTATION

THE HERITAGE RIVER PROPOSAL – CONSERVING AUSTRALIA'S UNDAMAGED RIVERS

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Abstract

The extensive development of water resources in Australia to support agricultural development has caused considerable degradation of Australian river-floodplain systems and caused considerable loss of biodiversity. Australian States, who are responsible for water resources planning, are establishing systems that have identified the few remaining undamaged river systems, and are attempting to protect them from further development. It is argued that the Federal Government could assist the States in this regard in ways that would help meet national commitments to the International Biodiversity Convention by establishing a series of Heritage Rivers under proposed amendments to the Environment Protection and Biodiversity Act.

Keywords: biodiversity, river protection, heritage rivers, conservation

INTRODUCTION

Australia has few rivers that have not been degraded by human activity. Changing catchment vegetation for agriculture, and the management and extraction of water for irrigation are two significant drivers of change. These activities have led to significant loss of biodiversity in the rivers and associated wetlands of the settled parts of Australia.

Australia signed the International Convention on Biological Diversity of 1992 in June 1993, accepting an obligation to protect biodiversity. Most of the effort so far has been directed towards terrestrial and marine ecosystems. While most States have adopted the rhetoric of conserving aquatic biodiversity, and some States have legislation, progress in implementation has been slow owing to lack of funding and commitment (Nevill 2001).

The recent independent report to the Prime Minister's Science, Engineering and Innovation Council (Morton *et al.* 2002) identified the considerable increase in cost of trying to restore damaged ecosystems compared with that of protecting them in the first place. Balmford *et al.* (2002) estimate that the overall benefit:cost ratio of an effective global program for the conservation of remaining wild nature is at least 100:1. The Morton *et al.* (2002) report identified aquatic conservation as one of three key priorities (the others being curbs on the broad-scale clearance of vegetation and introduction of exotic organisms).

It is urgent that Australia proceeds to provide some level of protection for its undamaged rivers before they too are lost to inappropriate development. There is an opportunity for a Federal Government program to work with the States to bring this about.

The state of freshwater biodiversity in Australia

Australian Catchment, River and Estuary Assessment, 2002

This assessment was undertaken as part of the National Land and Water Resources Audit. It examined 14,606 river reaches throughout the agricultural regions of Australia and reported an aquatic biota index (invertebrates) and a physical environment index. Each was reported separately in four bands (un-impacted reference condition and three bands of increasing level of impairment). On the biological assessment, one-third of the river length assessed (21,909 km) was to some degree impaired, meaning it has lost between 20% and 100% of the invertebrates that would be expected to occur in similar un-impacted reaches. Almost one-quarter of these rivers have lost at least 20% of the different kinds of aquatic invertebrates that would be expected to occur under natural conditions.

The environmental assessment that considered catchment disturbance, flow disturbance, nutrients/suspended solids and aquatic habitat indicated that 85% of reaches had been modified, largely by catchment activity. Nutrients and suspended solids are higher than natural in some 90% of river reaches. More than 50% of river reaches had impaired habitat, largely due to loss of riparian vegetation.

State of the Environment Report, 2001

The Australia State of the Environment Report 2001 identifies what we have already lost. Of 208 frog species in Australia, 20 are considered endangered and seven are vulnerable. Of more than 200 freshwater fish species in Australia, 11 are considered endangered and 10 are listed as vulnerable under the *Environment Protection and Biodiversity Conservation Act*. Thirty-five exotic fish species have become established in inland waters, with eight identified as having a significant adverse effect on biodiversity. Fifty-seven species of freshwater Crustacea are regarded as threatened. Some of the larger freshwater crayfish species are under considerable pressure from habitat loss and overfishing, and appear to have been lost in the Lower Murray. Numbers of platypus seem to have declined or disappeared in many catchments but reliable information is not available.

NSW rivers survey, 1997

In NSW, 25% of the species expected to occur were not found in the NSW Fish Survey, indicating the poor condition of many waterways, especially those in the Murray–Darling Basin (Harris and Gehrke 1997). Eight freshwater fish species are listed under NSW legislation as threatened, with others pending. Eleven alien species have been recorded in NSW inland waters, most in the highly regulated Murray–Darling Basin.

The limited understanding of aquatic ecosystems

Few Australians appreciate the interconnectivity of rivers and their floodplains, or of rivers and their estuaries. River channels carry the dry-weather flow, and the floodplain carries wet-weather flow. This is very obvious in some of our northern floodplain rivers, and yet until recently legislation did not cover these floodplain flows, which have in some places been harvested for irrigation. It is less obvious in many southern rivers, but all the same, the river, the floodplain and the associated floodplain wetlands need to be thought of and managed as a single system.

Similarly, there is little appreciation that rivers connect to estuaries, and that the pulses of fresh water may be important to the health of the estuary. There is evidence that the size of the prawn catch in northern Australia is driven by flood flows that establish the salinity regime of coastal waters. Despite these connections, we still get calls in Australia to turn the rivers inland and use this "wasted water" to make the deserts bloom.

There is widespread concern to ensure the maintenance and recovery of native fish and to protect water-birds as well as unique animals such as the platypus. There is less understanding that the maintenance of these 'icon' species requires aquatic systems that have adequate flow regimes and adequate water quality, and that the habitat in the streams and the connecting floodplains is appropriate for the various species of concern. There is a very limited appreciation of the fact that we cannot manage and maintain 'icon' species without maintaining the communities of which they are part. There is also widespread concern about the impacts of invasive species such as carp and some of the pest water plants (Cullen 2001).

WATER RESOURCE PLANNING IN AUSTRALIA

Water is a State responsibility in Australia, although the Federal Government has some interests and in the past has been a substantial source of funding for water resource development. Australian State and Federal Governments have just committed to a $A1.4 billion joint program to address issues of salinity and water quality, as a response to the degradation and the risks of salinisation. With such large sums being spent by governments to restore degraded systems, it is of concern that little is being spent to protect undamaged river systems. Morton *et al.* (2002) make it clear that repair is much more expensive than preventing damage in the first place.

Most States have moved beyond the sort of simplistic water planning that focussed on "yield" in terms of extracting water for irrigation. It is now understood that rivers are ecological systems that need to have some water left in them for ecological purposes. This understanding has come about only after extensive blue-green algal blooms and the loss of native fish that have reduced the amenity and utility of many waterways.

There has been considerable activity, stimulated by water reforms supported by the Federal Government, to identify and provide environmental allocations of water in rivers. Removing water from irrigators has been politically difficult, and achievements in providing adequate environmental flows have been slow, despite some progress.

The underlying reason for these environmental allocations is the desire to maintain the plants and animals that live in our rivers and on our river-floodplain systems. The scientific understanding of the requirements for individual species and for ecological communities is difficult, and a number of approaches have been developed for making judgements of appropriate flow regimes.

Water planning in most Australian States has identified rivers that have not been degraded, and has identified these as worthy of conservation (Anon 2002 for the Victorian work in this area). The protection given to these rivers under these arrangements is relatively weak, and it could be changed at the next revision of the water plan. Generally, these arrangements do not provide funding to develop plans or to manage these rivers.

Victoria does have a *Heritage River Act 1992* but has so far largely failed to implement it. New South Wales also has a capacity to establish freshwater aquatic reserves under its *Fisheries Management Act 1994*, but has chosen not to do so as yet.

CONSERVING AQUATIC BIODIVERSITY IN AUSTRALIAN FRESHWATER SYSTEMS

There are four main reasons why we need to maintain undamaged aquatic ecosystems (Cullen 2001):

- to provide "seeding" sources to help re-colonise areas that have been damaged;
- to provide benchmark reference areas so that we can assess how much our managed rivers have departed from the natural condition;
- to protect the aquatic species that live in these rivers. These organisms are of value in themselves, and the aquatic communities provide essential and often irreplaceable genetic material and ecosystem services; and
- to meet our international obligations with regard to biodiversity.

Connectivity and Seeding (Cullen 2002)

Rivers are linear systems and, to stay healthy, they need to be seeded with biological material from intact reaches and their floodplains. The need for connections, both up- and downstream and cross-ways, is now appreciated.

Rivers need upstream areas that are connected with the downstream, and not isolated by weirs. The channel that carries dry-weather flow needs to be connected with the floodplain during high flows. These connections are important to allow biological material to move up- and downstream and to move between the river channel and the floodplain.

During high flows, the river and its floodplains are recharged and replenished. The floodplains are flushed with a fresh supply of water and new inhabitants, while the river is recharged with nutrient-rich water from the floodplains and massive doses of organic material. Protection of selected tributaries in highly modified systems may be important to provide material to colonise areas being rehabilitated.

Reference areas as benchmarks of change

Australian Governments are supporting regional catchment groups to improve catchment management, to restore more benign flow regimes to our rivers and to remove weirs and provide fish ladders and aquatic habitat. It is important that we develop tools to evaluate the effectiveness of these investments, so as to ensure that we are getting value for money (Possingham 2001).

A central part of this assessment process requires us to have undamaged reference areas set aside and managed effectively so that we have something to compare treated areas with. There are very few such rivers left in the agricultural regions of Australia (Cullen 2002).

International obligations

Meeting international obligations in this area is difficult in Australia since the federal government has the responsibility for making international agreements but it does not have the constitutional responsibility for managing natural resources. It can only meet the international obligations through collaboration with the States, which often involves federal funding. Attempts to protect freshwater biodiversity have involved limited protection of some wetlands.

Identification of appropriate rivers for conservation

The Victorian River Health Strategy (Anon 2002) identified the characteristics of an ecologically healthy river as one having flow regimes, water quality and channel characteristics such that

- in the river and riparian zones, the majority of plant and animal species are native, and no exotic species dominate the system,
- natural ecosystem processes are maintained,

- major natural habitat features are represented and are maintained over time,
- native riparian vegetation communities exist sustainably for the majority of its length,
- native fish and other fauna can move and migrate up and down the river,
- linkages between river and floodplain and associated wetlands are able to maintain ecological processes,
- natural linkages with the sea or terminal lakes are maintained, and
- associated estuaries and terminal lakes systems are productive ecosystems.

Most jurisdictions have identified rivers of conservation value in their water planning and they are seeking to protect them from further development. The Paroo River and Coopers Creek are examples in Queensland; the Ovens and Mitchell Rivers in Victoria. Other important and relatively undamaged rivers worthy of attention include the East Alligator in the Northern Territory, the upper Clarence in New South Wales and the Fitzroy in Western Australia. The Barmah–Millawa wetlands on the Murray River are also recognised as priority conservation areas.

No States have undertaken extensive and comprehensive surveys of their aquatic resources, and so it is unlikely that the remaining undamaged rivers that have been identified give a comprehensive or representative collection of what should be protected (Nevill 2001). Although such surveys are desirable, it is important to protect what is still undamaged before it is too late.

Why protecting 'Icon' species is not enough

In Australia, as elsewhere, there has been significant activity in identifying and trying to protect threatened species. The common strategy is to develop recovery plans for these threatened species. Whether these plans have been effective awaits evaluation. The identification and protection of endangered species has been widely used in North America, and tough legislation is having an impact on development decisions that threaten these 'icon' species. This approach is a second-best option since often conflicts arise between the protection regimes required for different important species. In my view, we should put less emphasis on particular species and more into maintaining important ecological processes that allow systems to evolve and develop in response to the changing natural environment.

There have been efforts to restock aquatic ecosystems with artificially reared stock. This has not helped maintain genetic biodiversity in these systems.

Conserving a wide suite of organisms in an ecosystem ensures there will always be some than can do well under any particular conditions of flow, nutrient status, temperature and light conditions. As our water management activities stabilise flows and limit the number of habitats, we lose species and create aquatic monocultures that may not contain any organisms to take advantage of particular conditions that later arise. This puts the system at risk of domination by undesirable species, and this may then be impossible to reverse.

Part of this problem is our ignorance of the species we might lose, and of how they contribute to the functioning of the entire ecosystem. Who would have thought that a simple fungus might be critical until penicillin was discovered? We just do not know the benefit that many of the organisms at risk might be to us. Our ignorance is more profound at the ecological community level.

Australia has made an effort to identify and protect wetlands of national and international importance, and many of these have been designated under the Ramsar Convention. More than 50% of Australia's wetlands have already been lost, largely by drainage and conversion to agricultural land, or by removing the water that is needed to maintain them (Nevill 2001). The loss of this habitat then flows on to affect native fish and waterbird communities.

Although we designate important wetlands, we have limited management or assessment strategies for these important areas. It is impossible to manage "Ramsar Sites" in isolation from their catchments. If streams flowing into such wetlands were protected in some way it would help protect them. Declaring a wetland at the bottom of a system as important, and then allowing uncontrolled development of the catchment such as has been allowed in the Narran system makes the process ineffective.

The Ramsar Convention gives a framework to protect a wide range of waterbodies, but Australia has chosen to apply it in a narrow sense to static waterbodies.

The idea of heritage rivers

The independent report to the Prime Minister's Science, Engineering and Innovation Council (Morton *et al.* 2002) called for the establishment of a Heritage River system to protect the remaining undamaged rivers.

The Australian States have already identified some rivers that are presently relatively undamaged, and have recognised the importance of protecting them from development. However the present protection under State water planning is of a limited nature, and in revisions of the water plans the pressures to "develop" these water resources to provide for agriculture, urban uses and mining will increase as water becomes scarce and the price of it continues to escalate. Pressures in these situations can be intense, and so a system of designation in perpetuity such as we have developed for National Parks and Nature Reserves seems an essential step to long-term protection of these systems (Cullen 2001).

The IUCN has established categories of protected areas that allow for existing uses to be maintained. This is essential for gaining acceptance of the Heritage River idea for Australia, since there are few catchments without human activity, and many of them have established agricultural activities. However, these activities have had only minor impacts on the rivers and so can be maintained.

The major threatening process that must be controlled is the extraction of water from these rivers. Water extraction itself introduces a range of other damaging activities, including weirs that block fish passage, the intensification of land use through irrigation and the return of contaminated drainage waters. The existing agricultural activity in these proposed Heritage Rivers may be extracting water for stock and domestic purposes, but not for irrigation.

There are amendments to the *Environment Protection and Biodiversity Act* presently before the Australian Parliament that would allow this. The federal interest stems from Article 8 of the International Biodiversity Convention that allows for special measures to protect biological diversity. The Amendments under consideration allow for the declaration of places and the provision of financial and other resources for the planning and management of such places to maintain biological diversity.

Under such proposed designation, the existing users would be able to maintain existing levels of extraction of water and catchment development, but additional water extraction would be prevented, thus ensuring the security of landholders and ecosystems downstream. It is proposed that no Heritage River should have more than 5% of its mean annual flow diverted from the river.

The management of heritage rivers

Designation of appropriate rivers as Heritage Rivers under the EPBC Act would provide long-term protection of these rivers. It would also provide access to federal funding either to State agencies or to regional catchment authorities to plan and manage these rivers.

Initial Planning and Ecological Survey

Federal funding should be made available to carry out an initial ecological assessment of each Heritage River. This would include an invertebrate survey, a fish survey and a survey of riparian vegetation. If significant wetlands are involved, a study of wetland vegetation and water-birds should be included. These studies are designed to establish a baseline from which change over time can be measured.

A planning study should build upon these ecological studies and identify the other threatening processes that might degrade the ecological integrity of the river and identify management strategies to minimise any such impacts.

These reconnaissance and planning studies should be completed within two years, and a planning grant should be made available to undertake them. These studies should report on the ecological assets and the ecological services provided by the river, identify important threatening processes and make plans for appropriate interventions.

In many catchments a variety of threatening processes occur, so it may be necessary to have a suite of targeted interventions. Continuing investment in one intervention may be ineffective if it is some other factor degrading the system. In these situations, an adaptive management framework is recommended where outcomes are predicted and then measured through adequately designed monitoring. The use of adaptive management means that the mix of interventions can be changed if the desired outcome is not being obtained (Table 1). We should limit the following processes that threaten the Heritage Rivers:

- any further clearing and changes of catchment land use;
- any further licences to extract water;
- any further weirs or structures;
- any de-snagging or other "river-protection" activity;
- any further drainage of existing wetlands;
- any further levees that stop floodplain inundation;
- any stocking with non-native fish;
- invasions by exotic fish or other organisms;
- any commercial fishing and possibly a proportion of recreational fishing; and
- any further clearing of riparian vegetation.

Table 1. Management Activities to Maintain or Restore Biodiversity in Aquatic Ecosystems (from Cullen 2002).

Possible intervention	**Physical extent of benefit**	**Chance of beneficial outcome**	**Cost**
Do not remove snags or alter hydraulic conditions by bank stabilisation works	Local–Regional	High	None
Replace snags	Local	High	Low
Install fish ladders on large dams	Regional	Moderate	High
Install multi-level offtakes on large dams	Several hundred km	High	Very High
Remove weirs	Extent of weir pool at least	High	Low
Install fish ladders on weirs	Length of weir pool	Moderate to high	Medium
Introduce environmental flows, possibly through purchase of entitlements	Whole river downstream	High	High
Remove levee banks	Regional	High if floodplain not degraded	Low
Protect riparian vegetation	Local to whole system	High	Low to medium
Prevent stock grazing wetlands	Local	High	Low
Prevent introduction of exotics	Whole river	Medium	Medium
Remove exotic species	Regional	Low	High
Reduce fishing pressure	Local to whole river	High	Low
Manage urban stormwater	Regional	Depends on relative contribution	Medium
Impose best-management practice on farmland to reduce pollution	Regional	High	Medium
Restocking with native species	Local to whole river	Medium	Low
Education to develop a water-literate community	Regional	Medium	Low

Ongoing management of heritage rivers

Once the necessary studies have been undertaken and a management plan develops that meets local, State and national interests, there should be ongoing funding to allow implementation of the plan.

There are four elements to the implementation of a Heritage River Management Plan:

- implementation of the actions identified in the Management Plan;
- implementation of an ongoing public education and interpretation plan;
- access to funding for unexpected threats such as introduction of exotics, and
- funding for a five-yearly ecological study that makes a public report on the health of the River.

A classification for Australian rivers

The Australian community is having difficulty in understanding what needs to be done to protect the health of rivers and is concerned by the present levels of degradation. There are many threatening processes and many articulate interests.

It is argued here that flow diversion is the most important threatening process, and one that is easily understood and managed. There are other factors that also damage rivers, and may alter their location within the classification below, but a flow classification could be useful in water planning in Australia.

Table 2. Australian River Classification

River Class	Maximum Mean Annual Flow Extraction
Heritage River	< 5%
Conservation River	< 15%
Sustainable Working River	< 33%
Managed Working River	< 67%

The beauty of such a classification based on a single explicit measure is that it feeds directly into planning. If governments choose to allow additional extraction in a river, they may move it down a class, subject to a detailed assessment and community consultation process, consistent with a detailed protocol for changing classes. If they reduce extractions it may move up a class. The consequences of government allocations are very transparent on river health. The classification is clearly inappropriate where there is a significant pollution load from the catchment.

Diversions from a river system would not be permitted to exceed the level for that category for the life of the planning framework (say 30 years). Strict protocols for auditing and changing a river's category during this period would need to be developed and administered.

This sort of classification allows the identification of important ecological and biodiversity assets and their protection from incremental development of water resources. It provides clear direction on the consequences of development of these water resources on the health of the river. This provides security for the environment while directing future water-resource development within a strategic planning framework.

This approach is consistent with and allows for implementation of the 1994 COAG water reforms already agreed by State and federal governments. These require that States determine allocations of water for the environment to maintain the health and viability of river systems and groundwater basins (clause 4). Where future activity was planned, the environmental requirements of the system need to be adequately met before any water harvesting may occur (clause 4f) and any proposed water development scheme should be economically and ecologically viable (clause 3diii).

CONCLUSIONS

I start from two simple and demonstrable propositions.

Firstly, Australia has lost much of its aquatic biodiversity through the degradation it has allowed through the mismanagement of water resources to support agricultural development. Secondly, it is costing large amounts of money to attempt to restore degraded systems, and restoration may not be possible. It is 10 to 100 times more cost effective to prevent degradation in the first place rather than attempt repair.

Most Australian States have now put in place water-resources planning frameworks that have identified the small number of river systems that are as yet not degraded, and are attempting to restrict development in these rivers to protect them. However, most of these State arrangements do not provide long-term protection, and none have provided the financial resources for adequate planning and management of such rivers.

There is a real opportunity for the Federal Government to support the States in this endeavour, and to help meet the federal obligations under the International Biodiversity Convention and the *Environment Protection and Biodiversity Conservation Act*. This would be highly cost-effective in terms of the funds the Federal Government is now expending to restore damaged aquatic ecosystems.

It is important to gain the support of landholders for this initiative. To gain widespread support it is necessary to protect existing land uses but to prevent escalation of water extraction from the Heritage Rivers. It is necessary to build a constituency of landholders and conservation, recreation and indigenous interests to encourage governments to invest to ensure the protection of our remaining undamaged waterbodies.

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Marine Fisheries of the USA: Moving from Single-Species Management to a More Holistic Ecosystem-Based Approach*

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Introduction[A]

The USA contains more than 152,000 km of coastline, with more than 5.4 million km^2 within its territorial waters; these waters are commonly referred to as the US Exclusive Economic Zone (EEZ). The EEZ is a political designation that begins outside state waters (~ 5 km) and extends seaward some 320 km (Fig. 1). The USA claims sovereign rights and exclusive fishery management authority over all fish, and all Continental Shelf fishery resources, within this area. Covering portions of the Atlantic and Pacific Oceans, Caribbean Sea, Gulfs of Mexico and Alaska, and islands in the western Pacific, the EEZ of the USA is the largest in the world. The enormity and importance of the marine EEZ of the USA is clear when one realizes that the EEZ is approximately 1.7 times larger than the entire USA and territorial land mass.

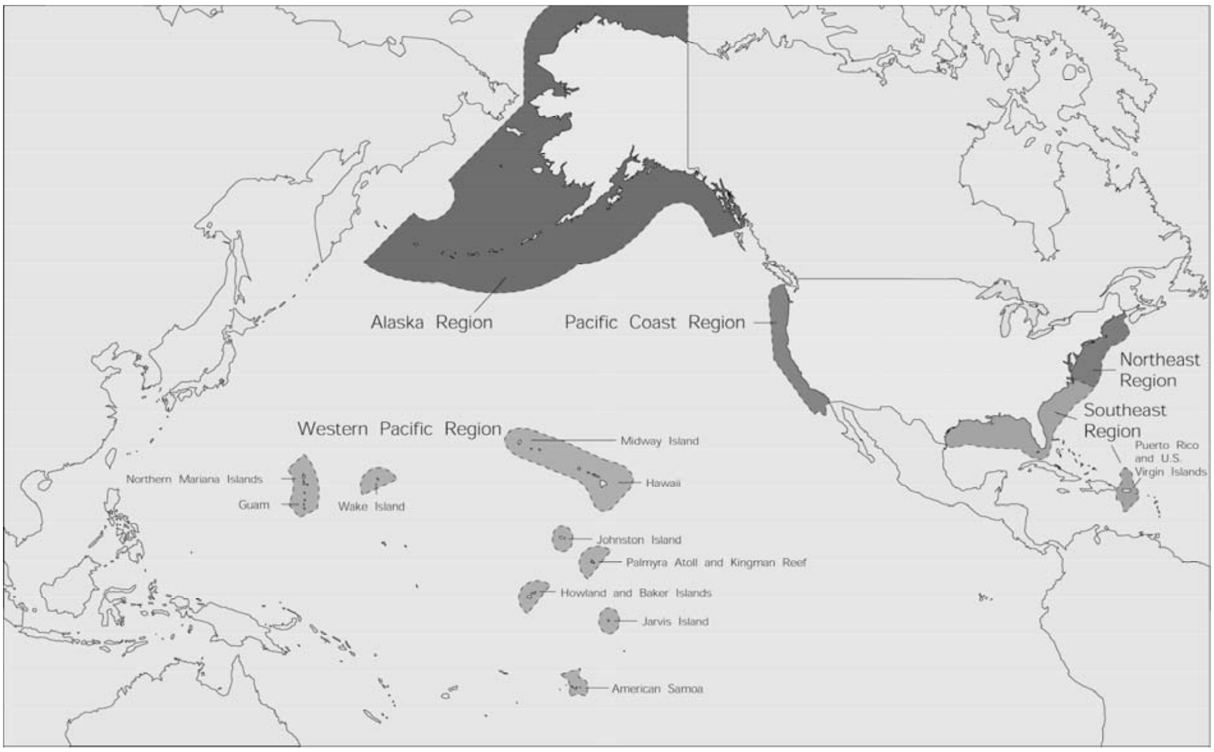

Fig. 1. Exclusive Economic Zone (EEZ) of the United States of America.

This vast marine environment provides vital environmental and economical services to the nation. As more than half of the population of the USA lives in close (90 km) proximity to the coast, pressure from recreational activities in the form of swimming, boating, and fishing continues to increase. Living marine resources (LMRs) directly and indirectly support extensive industries in the USA. Commercial and recreational fishing significantly contributes to the economy of the nation and constitutes a major source of employment to many coastal communities. In 2000, for instance, 20 billion kg of LMRs were estimated at US$3.5 billion from commercial landings alone by USA fishers (where 'billion' signifies one thousand million). Additionally, it has been estimated that recreational fishermen took 76 million fishing trips and caught 429 million fish (NMFS 2002).

FISHERIES MANAGEMENT IN THE USA

Maintenance of sustainable fisheries with this ever-increasing demand on the resources represents an extremely complex and often controversial challenge. The National Marine Fisheries Service (NOAA Fisheries), part of the US Department of Commerce's National Oceanic and Atmospheric Administration (NOAA), has been entrusted with the nation's LMRs and is the agency responsible for science-based conservation and management of these resources. When NOAA was established in 1970, one of the primary missions of the agency was to develop the nation's underutilized fisheries. Unfortunately, much has changed since the 1970s, as the past three decades have seen overcapitalization of the nation's fishing fleets and continued decline of fish stocks.

While the *Marine Mammal Protection Act of 1972* and *Endangered Species Act of 1973* indirectly may provide protection to some fish stocks, the landmark legislation governing fisheries management in federal waters of the USA was crafted in 1976 with the passage of the *Magnuson–Stevens Fishery Conservation and Management Act* (herein known as the *Magnuson Act*). The *Magnuson Act* has since achieved the stated goals of nearly eliminating foreign fishing from the US EEZ and developing domestic fisheries. The *Magnuson Act* also created eight Regional Fishery Management Councils (FMC) throughout the country who, acting on behalf of the federal government, are charged with conserving and managing fisheries resources under their regional jurisdiction. This process involved developing individual fishery management plans (FMPs) and proposing regulations governing the individual species. The Councils comprise scientists, fishing industry representatives, consumer and environmental organizations, the general public, and political representatives. Although this diverse membership ensures that all segments of fisheries participate in, and advise on, the content of the FMPs, it can sometimes be contentious and inefficient because of the very different mindsets of these groups. The *Magnuson Act* also requires the Councils to achieve a balance between science and economics. This balance has proven to be elusive at times and the Councils often are criticized by those that feel that the FMP is weighted much more to one segment than the other (e.g. economics *v.* conservation). The national standard for fishery conservation and management strives for measures to prevent overfishing, yet equally strives for extracting the maximum sustainable yield (MSY) from each fishery. Since the passage of the *Magnuson Act* in 1976, decisions of the Councils have not always achieved this balance nor reversed the decline of many fish stocks; this failure has been due to competing interests, political pressure, and unreliable scientific data.

Realizing this continued decline, Congress amended the *Magnuson Act* and passed the *Sustainable Fisheries Act* (SFA) in 1996. The SFA noted that certain stocks of fish continue to decline and that their survival is threatened if fishing pressure is not reduced and important habitat is not protected. Hence, the SFA required the FMCs to develop FMPs that minimized bycatch and disturbance to important habitat caused by fishing gear, to end over-fishing, and to devise a plan to rebuild overfished stocks. For the first time since the passage of the *Magnuson Act* in 1976, the SFA amendments make the duty to protect fish stocks and to eliminate overcapitalization and over-fishing an enforceable legal obligation.

It is clear that one of the primary objectives of USA fisheries management is to develop sustainable fishery harvests that minimize the risk of overfishing. This has been a very difficult goal to realize, because many stocks are managed "at the edge" as a result of heavy social and economic considerations to maximize harvest wherever and whenever possible. In this management scenario, imprecision in stock assessments can lead to population crashes in the fishery. Therefore, comprehensive and accurate data on landings and fishery-independent monitoring surveys are of paramount importance. Output controls that attempt to limit the number/weight of a given species that can be harvested (e.g. total allowable catch) are based on analyses of these data. Collection, analysis, and interpretation of all the information necessary (Fig, 2) to estimate a stock size and estimate the amount of fish that can wisely be harvested fluctuates annually and is subject to a considerable amount of uncertainty.

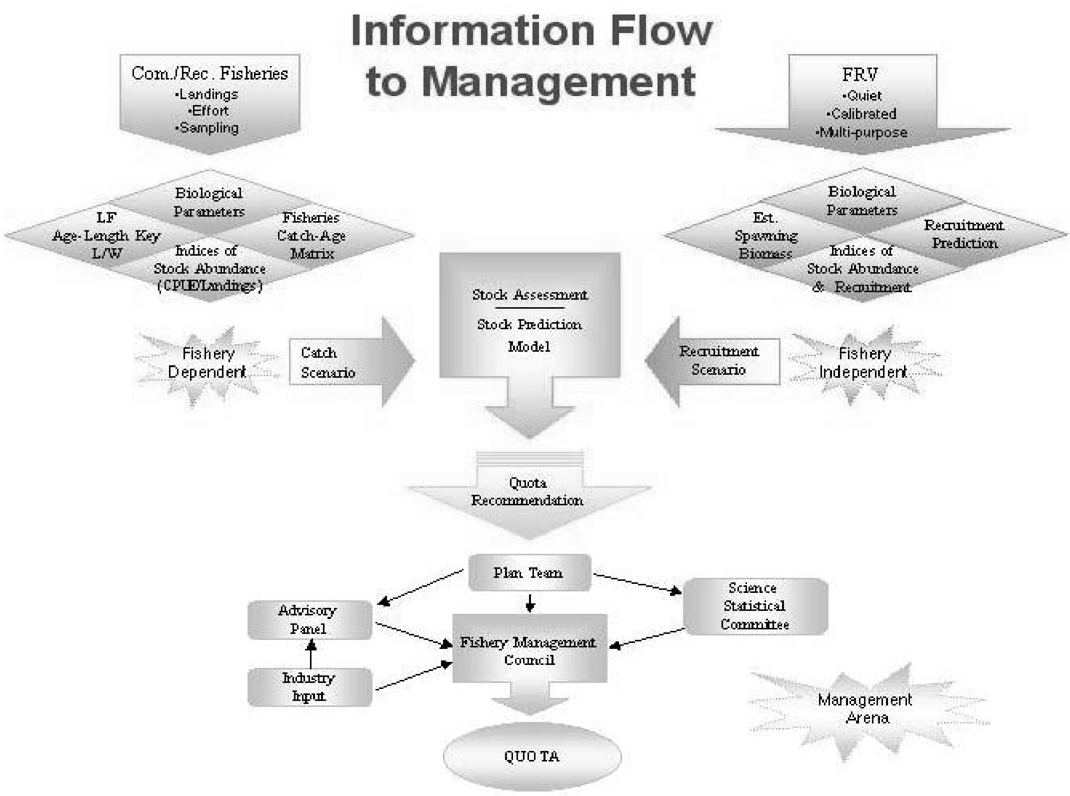

Fig. 2. The flow of scientifically sound information and data to support fishery conservation and management.

Abundance estimates from research surveys and virtual population analysis (VPA) are used to set catch quotas in the USA. VPA relies upon commercial catch-at-age data to reconstruct past stock abundances and makes several assumptions. Abundance estimated from research surveys can be highly variable, partly because gear efficiencies may change from year to year. Often, trends in abundance as determined by VPA do not track those derived from research surveys. Population abundances can be overestimated and fishing mortality underestimated because of uncertainty. These discrepancies cause ill-supported management decisions and can lead to fish stock collapse as witnessed in the Atlantic Ocean off Canada for the cod fishery.

What has emerged through these many fluctuations and uncertainties is a complex set of evolving regulations and amendments that make monitoring, conducting, and enforcing fisheries in the USA difficult for everyone. For instance, in 1996 alone, 855 regulatory actions were processed through the Federal Register to implement and amend rules and actions for domestic fishing in the USA. What ultimately occurs is a mixture of seasonal closures, gear restrictions, and limits on the number of fishing days.

Present interest in simplifying regulations and better protecting fish stocks and their habitat through the use of marine protected areas (MPAs) reflects dissatisfaction with conventional fishery management. Ecosystem-based approaches in fisheries management that take into account unintended consequences of fishing (bycatch and habitat degradation), important interactions among various species, and uncertainty of stock assessments may be an attractive supplement to the management of single species. Executive Order 13158: Marine Protected Areas, implemented in 2000, recognizes that reducing effort and fishing mortality to an acceptable level in order for stocks to rebuild *may* require areas to be set aside, free from extractive uses, in order to provide insurance against natural fluctuations and scientific uncertainty. In the 1990s, several area-based Federal Fishery Management Zones were designated to restrict specific types of fishing gear or eliminate all extractive uses in order to provide added protection to important habitat and spawning aggregations, reduce fishing mortality, conserve biodiversity, and rebuild fish stocks.

In 1996, 39 FMPs guided the management of 727 species. NOAA Fisheries found that 86 species (12%) were overfished, 10 (1%) were approaching overfished status, 183 (25%) were not overfished, and the status of the remaining 448 species (62%) was unknown. Clearly, today's individual-stock and single-species management appears ineffective at times and new approaches need to be explored. The case studies that follow describe this new paradigm: area-based management that reduces fish mortality, bycatch, habitat destruction, user conflicts, and the consequences of stock-assessment uncertainty. Instead, these areas rely on the precautionary approach of areas set aside to act as insurance against unforeseen climatic events, poor recruitment years, and scientific uncertainty.

CASE STUDY: CAPE CANAVERAL, FLORIDA[B]

Two unintended reserves were created starting in 1962 at Cape Canaveral, Florida, when two estuarine areas in the Merritt Island National Wildlife Refuge (MINWR) were closed to all public access for security of the John F. Kennedy Space Center. This action created the oldest and, until 1999, the largest no-take reserve in North America. Johnson *et al.* (1999) reported on studies conducted in the 1980s, which showed that three areas without fishing had significantly higher average fish biodiversity and more abundant and larger exploited-fish species than three surrounding areas with fishing. Standardized catch-per-unit-effort (CPUE), adjusted to account for habitat differences between areas (i.e. depth, salinity, and submerged aquatic vegetation), showed that fishing was the primary factor accounting for differences between areas among exploited species. CPUE in closed areas for important gamefishes were 12.8 times greater for black drum (*Pogonias cromis*), 6.3 times greater for red drum (*Sciaenops ocellatus*), 2.3 times greater for spotted seatrout (*Cynoscion nebulosus*) and 5.3 times greater for common snook (*Centropomus undecimalis*).

The effects of closed areas on surrounding recreational fishing were reported by Roberts *et al.* (2001) on the basis of an analysis of International Gamefish Association (IGFA) world records from 1939 through 1999. Tested were hypotheses predicting that a significantly higher concentration of world records would occur near reserves than elsewhere in Florida and that disproportionate increases would occur after areas were closed to fishing. An alternative hypothesis was that since a smaller area was available to fishing, fewer world records would occur around Cape Canaveral. Data supported the two primary hypotheses for all three year-round resident gamefishes: 62% of all 39 Florida world records for black drum, 54% of 67 for red drum, and 50% of 32 for spotted seatrout were reported within 100 km (60 miles) of reserves (~13% of the Florida coast). As predicted, the proportion of records around closed areas also increased significantly after areas were closed to fishing. In addition, common snook, which was not reported from the Cape between 1959 and 1962, before areas were closed to fishing, had became established by the 1980s, although only 4 of the 84 world records from Florida were reported from the Cape.

Some of these records were undoubtedly the result of spillover, the movement of individuals from protected areas into surrounding areas. This conclusion is supported by tagging studies showing movements of fishes into and out of protected areas (Johnson *et al.* 1999; Stevens and Sulak 2001). It is also possible that greater reproduction of large individuals in reserves contributed to a larger population base from which some individuals survived to attain large size. This possibility is supported by Johnson and Funicelli (1991), who demonstrated that reproduction occurred at the Cape.

Over the study period, Florida's human population increased from 5 million in 1960 to 16 million in 2000. Recreational angling presumably increased in similar proportion. To compensate for increased fishing pressure, Florida has enacted many conservation measures to reduce total fishing mortality. These measures include the gradual elimination of commercial fishing by prohibiting the sale of sport fishes and a statewide commercial net ban in 1995. Florida has also regulated sport anglers by closed seasons, daily bag limits, and minimum and (for some species) maximum size limits. Because most conservation measures apply statewide, they alone are unable to explain the high concentration and increases in records around Cape Canaveral. The net ban, for example, certainly reallocated landings from commercial to sport anglers, but cannot explain the pattern of world records around the Cape which began increasing years before the net ban. The habitat in MINWR is excellent for sport fishes but the possibility that it was somehow unique, independent of the closed areas, does not explain the significant record increases after areas were closed to fishing. The simplest explanation for the data is that no-fishing areas reduced total fishing mortality and led to more world records in surrounding areas. The results from this case history confirm predictions that no-take reserves can support sustainable fishing for multi-species, especially when used in conjunction with other fishery conservation measures.

CASE STUDY: FLORIDA KEYS NATIONAL MARINE SANCTUARY

On 1 July 1997 the Florida Keys National Marine Sanctuary (FKNMS) established 18 no-take Sanctuary Protected Areas (SPAs) and one 10 nmiles² no-take Ecological Reserve in the Western Sambo region of the lower Florida Keys. An additional four SPAs were established to limit fishing to recreational trolling only. Since then, annual underwater visual surveys have been conducted to assess changes in reef-fish populations in areas open and closed to fishing. Extensive baseline data were collected between 1994 and 1997 from reefs eventually closed to fishing, as well as from reference reefs left open to fishing.

Preliminary data show that mean density (number of individuals per sample) of populations of important exploited reef species have increased significantly at protected reefs and were higher than on fished reefs. Yellowtail snapper (*Ocyurus chrysurus*), for example, supports the most important reef-fish fishery (Fig. 3) and was the first species to show a significant population response to protection from fishing.

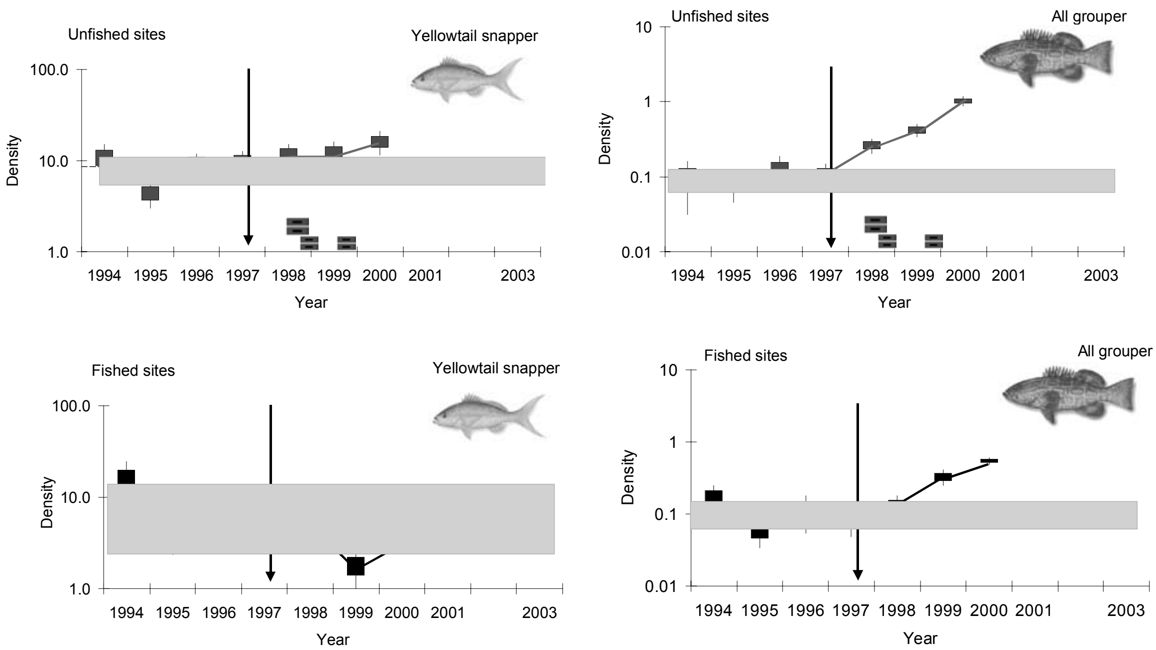

Fig. 3. Density trends for yellowtail snapper (left) and exploitable grouper (right) from Florida Keys reefs open to fishing (bottom) and protected from fishing (top). Vertical bars: 95% confidence interval. Boxes: + 1 standard error. Bold vertical line: initiation of no-take protection in 1997. Dashed line: 1994–97 mean density. Shaded band: 1994–97 annual baseline performance based on the 95% confidence intervals (projected beyond 1997 to show predicted density ranges if no changes occurred). Hurricane symbols: hurricanes on the lower Florida Keys in 1998 and 1999. From Bohnsack et al. (2001).

Mean density initially was significantly higher in no-take zones than in fished sites, but it increased significantly in no-take zones compared with the 1994–97 baseline, while no significant changes occurred in fished sites. The mean density of combined exploited grouper (Serranidae) species has increased both at fished reference reefs and in no-take zones since 1997 and currently is approximately an order of magnitude higher than that during the baseline period. Densities in no-take zones, however, have increased faster that in fished reference areas, especially in 2000 and 2001, the third and fourth year following protection. Mean density of gray snapper (*Lutjanus gresius*) was higher in no-take zones than in fished reference areas every year since 1997. In contrast to exploited species, two species not targeted by fishing show different trends. Striped parrotfish (*Scarus croicensus*), a small herbivore, and stoplight parrotfish (*Sparisoma viride*), a large herbivore, showed no significant increases in abundance since the closure of reefs to fishing. High concordance in mean density was observed each year in both fished and unfished areas over the study period. Years with drops or increases in mean density were observed on both reference and protected reefs.

In summary, since no-take protection was initiated in 1997, several exploited species have shown significant increases within no-take zones in density and average size of exploitable-phase individuals, while no significant changes have been observed for non-exploited species. For two exploited species, average size and density of exploitable-phase individuals also increased significantly in fished reference areas, but the magnitudes of these increases were still significantly lower than the increases observed in no-take zones. These results support the necessary predictions of marine reserve theory that population abundance and size of exploitable fish will increase within areas protected from extraction. Because the total area of no-take zones is only approximately 0.5% of the FKNMS, measurable effects on total fishery yield are unlikely; however, edge effects, a concentration of fishing around reserve borders, have been noted.

In 2001, two ecological reserves covering a combined area of 151 nmiles^2 were established in the Tortugas region, west of the Florida Keys. In addition, Dry Tortugas National Park has approved the creation of a 46 nmiles^2 Research Natural Area that will offer additional habitat and population protection in an area contiguous with ecological reserves in the FKNMS. Although it is premature to make any conclusions about changes in the Tortugas, the region will be periodically monitored for changes.

CASE CTUDY: CLOSED AREAS ON GEORGES BANK[c]

The rich fishing grounds off New England played an essential role in the early economic development of the USA. The bountiful resources of Georges Bank, in particular, long supported fishing communities in this region. By the beginning of the 20th century, decline of some important resource species such as Atlantic halibut had already occurred. With the advent of distant-water fleets operating off the New England coast in the early 1960s, however, a pattern of sequential depletion of groundfish and small pelagic species was established, leading to a series of management measures by the International Commission for Northwest Atlantic Fisheries intended to stem overfishing of these valuable resources (Fogarty and Murawski 1998). As part of this effort, seasonal closures of portions of Georges Bank were implemented in 1970 with the objective of protecting spawning aggregations of haddock (Halliday 1988; Murawski *et al.* 2000). In 1994, year-round closure areas were established on Georges Bank based on these earlier seasonal sites, and an additional closure area off southern New England, designed to protect yellowtail flounder, was based on earlier seasonal closure areas for this species (Fig. 4).

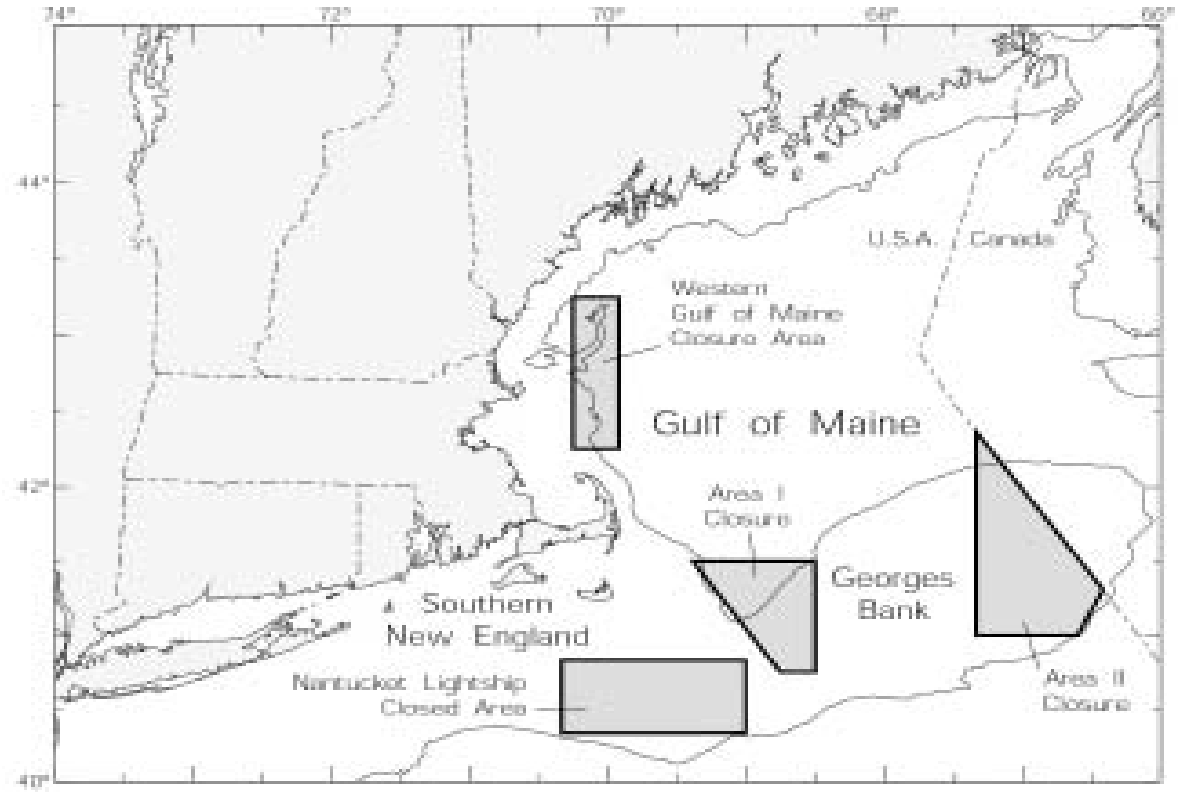

Fig. 4. Location of year-round closed areas off New England.

These three areas encompassed 17,000 km^2. Use of fishing gears capable of retaining groundfish, including trawls and scallop drags, was prohibited in the closed areas. Closure areas were subsequently adopted in the western Gulf of Maine to protect groundfish resources and in the mid-Atlantic Bight to protect scallops.

Groundfish resources

Establishment of the year-round closed areas on Georges Bank and southern New England coincided with sharp reductions in fishing effort (days-at-sea), mandated under Amendment 5 of the Northeast Multispecies Groundfish Management Plan, and with other measures such as mesh regulations and minimum legal size limits; this complicated efforts to determine the effects of the closures. A 41% decline in days-at-sea was effected over the first three years of this management regime; during this period, the fishing mortality rates of cod, haddock and yellowtail flounder declined by 62%, 68%, and 88% respectively (Murawski *et al.* 2000). The imposition of the closed areas presumably accounts for the enhanced reduction in fishing mortality relative to the reductions in fishing effort (Murawski *et al.* 2000). The lower CPUE (and overall removals from the stocks) in the open areas relative to the closure areas are a major contributor to the reduction in fishing mortality rates for cod and yellowtail flounder in particular.

The major groundfish stocks on Georges Bank have responded differentially to these management measures. Sharp reductions in overall exploitation rates for Atlantic cod since 1994 have resulted in a 50% increase in spawning-stock biomass (Fig. 5a). This increase in biomass is attributable to increases in mean size accompanying increased survival rates for age classes vulnerable to the fishery. No evidence of increased recruitment (numbers of age-1 Atlantic cod) has been noted. In contrast, spawning-stock biomass of haddock on Georges Bank has increased by 400% since 1994, reflecting both improved recruitment and increased mean size of adults (Fig. 5b). The 1998 year class of haddock is the largest in two decades (although still lower than historical median recruitment levels. For yellowtail flounder, dramatic increases in recruitment since 1994, coupled with increased mean size in the adult population, have resulted in an 800% increase in spawning-stock biomass (Fig. 5c).

The differential response of cod, haddock, and yellowtail reflects differences in distribution and seasonal movement patterns relative to the closed areas and differences in life-history characteristics. Closed Area I (see Fig. 4) provides year round protection for cod and particularly for the western spawning component of haddock (Brown *et al.* 1998). Closed Area II provides effective protection for cod and haddock during winter-spring; however, during summer and autumn, these species are distributed in deeper, colder waters, including the Northeast Peak of Georges Bank under Canadian jurisdiction. Harvesting of cod and haddock is permitted in Canadian waters only during the second half of the year. Yellowtail flounder are comparatively sedentary, with significant distributions on both sides of the international boundary throughout the year. Recent studies employing monthly trawl surveys indicate some seasonal movements especially associated with closed area II.

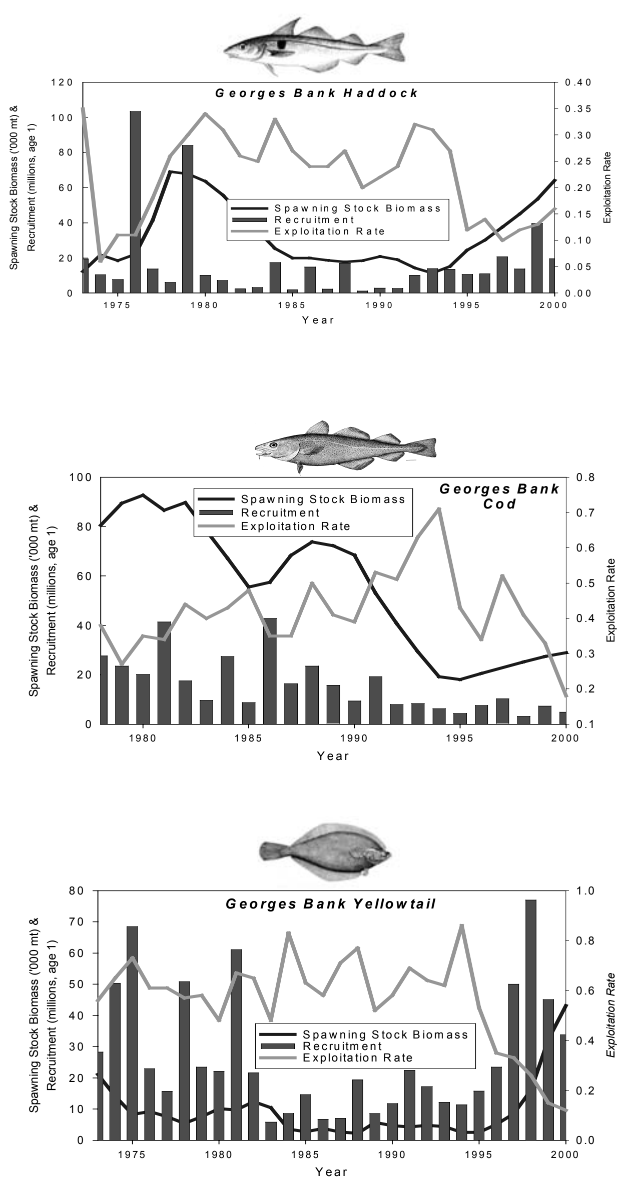

Fig. 5. Trends in exploitation rates, recruitment (age-1 fish) and spawning-stock biomass for (*a*) Atlantic cod, (*b*) haddock and (*c*) yellowtail flounder.

Sea scallops

The effects of implementation of closed-area management strategies on Georges Bank and in southern New England need to be considered in concert with other management strategies designed to reduce overall levels of fishing effort. Although the year-round closed areas in this region were established specifically to meet groundfish management objectives, these closures had important incidental benefits for scallop resources.

The Atlantic sea scallop *Placopectin magellanicus* supports the second most valuable fishery (after the American lobster) in New England. By the mid 1990s, the scallop resource on Georges Bank had been sharply depleted in the boom-and-bust pattern characteristic of this fishery. Prohibition of scallop fishing within the areas on Georges Bank that were closed to groundfish in 1994 therefore met with little resistance from scallop fishers.

Resource surveys conducted by the Northeast Fisheries Science Center have shown that sea scallop biomass within the closed areas on Georges Bank has increased 16-fold since 1994 (Fig. 6); an approximate 4-fold increase has been observed in the open areas during this period. Dramatic increases in mean size of scallops in the closed areas and widespread strong settlement in 2000 have accounted for the overall increase in biomass for this species.

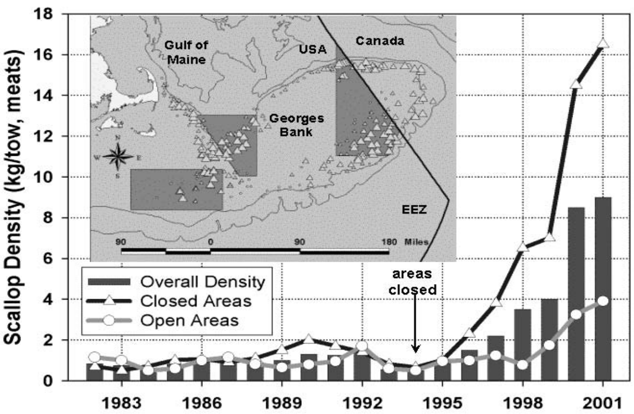

Fig. 6. Trends in sea scallop density in open areas, closed areas, and the total area on Georges Bank.

Dispersal of sea scallops is predominantly in the larval phase; juveniles and adults are relatively sedentary although they are capable of movement. This species is therefore particularly well suited to protection by closed-area management. Hydrodynamic–biological models indicate that the closed areas on Georges Bank are self-seeding for scallops and also that the closed areas potentially contribute recruits to the open areas. An understanding of this spill-over effect is essential to predicting the potential benefits of the closed areas to the scallop fishery.

CASE STUDY: THE COWCOD CONSERVATION AREAS OFF SOUTHERN CALIFORNIA[D, E]

For the past several decades, more than 52 species of rockfishes (genus *Sebastes*) and the lingcod (*Ophiodon elongatus*) formed the basis of very large recreational and commercial fisheries along the Pacific Coast of the USA and Canada. With a recreational value estimated in the billions of dollars and commercial value in the many tens of millions of dollars, these fisheries helped support the economic health of many coastal communities.

Today, there is abundant evidence that these fisheries are in severe decline (Ralston 1998; Pacific Fishery Management Council 1999). At least three important events have combined to drastically reduce the populations of many of these species. First, overfishing has substantially reduced the numbers of subadults and adults. Many of these species have extreme life spans (to 100+ years), are slow to mature (3–20 years of age), and reproduce every year of their adult life (Love *et al.* 2002). Consequently, overharvesting likely has also reduced the number of young rockfishes being produced. Second, in the past twenty-five years, adverse oceanic conditions have contributed to increasingly poor survivorship of young stages of these fishes, again leading to fewer juveniles to replace those that are caught (Roemmich and McGowan 1995; Love *et al.* 1998; Moser *et al.* 2000). Third, there is evidence that some fishing gear, particularly some types of bottom trawls, can be destructive to seafloor habitats (Collie *et al.* 1997; Jennings and Kaiser 1998). This, too, could diminish the survival of both young and adult rockfishes and lingcod.

A number of these species are currently declared overfished by NOAA Fisheries. By way of example, the bocaccio, *Sebastes paucispinis*, was once arguably the most valuable rockfish in California waters. Throughout the twentieth century, recreational and commercial fishermen took millions of individuals, and it was among the most important species at virtually all ports. It was quite likely the dominant species over most deep-water (100–250 m) rocky habitats. A recent assessment estimated that the bocaccio population off California now is 12% of the 1970 spawning output and 16% of 1970 total biomass. It will take 20 to 25 years to rebuild this population to 40% of historic levels (MacCall 2003).

Cowcod are one of the largest West Coast rockfishes, growing to 100 cm (39 inches). Although never as abundant as bocaccio, commercial passenger fishing vessels (CPFV) often targeted this species. Historically, they were most abundant in the waters around some of the islands and offshore banks of the southern California Bight (MacGregor 1986; Moser *et al.* 2000; Butler et al. 2003). Cowcod biomass presently is estimated to be about 7% of unfished biomass; it will likely take close to 90 years to rebuild to this population to 40% of historic levels (Butler et al. 2003).

It is clear that abundance of both species, estimated from CPUE from creel censuses of CPFVs, was highest during the 1970s, declined in the 1980s, and had declined further by 1999 (Fig. 7). Mean annual CPUE for bocaccio in the 1970s was roughly twice that of the 1980s and 20 times that in 1999. A similar decline in mean annual CPUE occurred for cowcod.

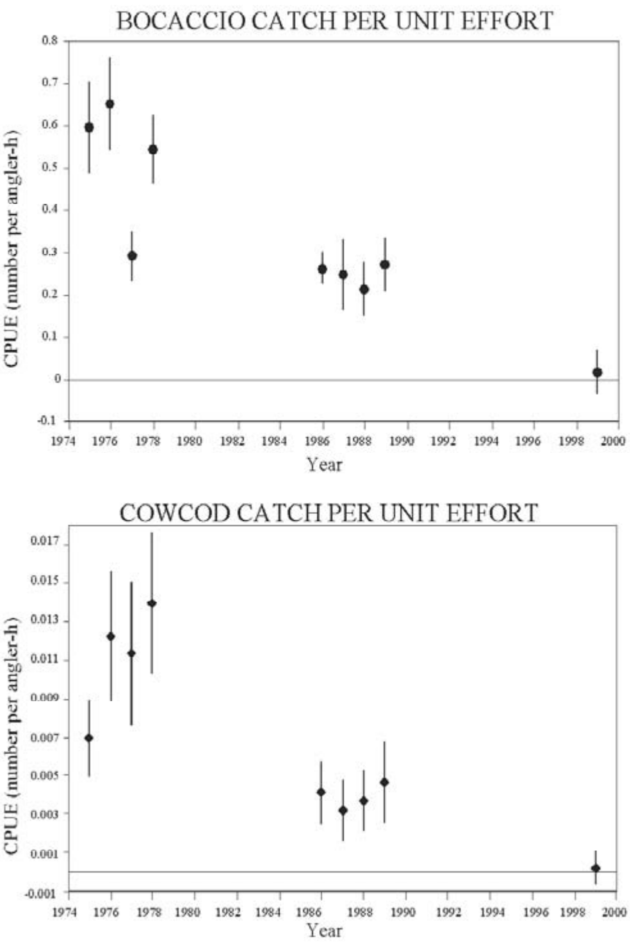

Fig. 7. Annual mean catch per angler-hour (CPUE) of bocaccio and cowcod taken in the southern California commercial passenger fishing-vessel fishery, 1975–78, 1986–89, and 1999 (vertical bars are estimated standard error).

The Pacific Fisheries Management Council (PFMC), acting on behalf of the federal government as administered by NOAA Fisheries, is responsible for assessing and managing most groundfish populations from Washington to California and, in the past few years, has acknowledged that many are in severe trouble. By 2000, it was apparent that measures previously considered radical were necessary if some rockfish stocks were to recover off California. As a first step, beginning in 2001, the PFMC eliminated directed fishing opportunities for cowcod in southern California. Retention of cowcod was prohibited for all commercial and recreational fisheries. And, in an unprecedented effort to protect cowcod from incidental harvest, the Council established two Cowcod Conservation Areas (CCAs) in the Southern California Bight (Fig. 8). These two areas, encompassing about 14,750 km^2 (4,300 nautical miles^2), include key cowcod habitat and areas of relatively high cowcod catches. Fishing for all groundfish is prohibited year-round within the CCAs, with the exception that nearshore rockfish, cabezon, and greenling may be taken from waters where the bottom depth is less than 36.6 m. It is important to note that these closed areas protect far more than cowcod, serving to protect at least 50 other species of rockfishes and lingcod.

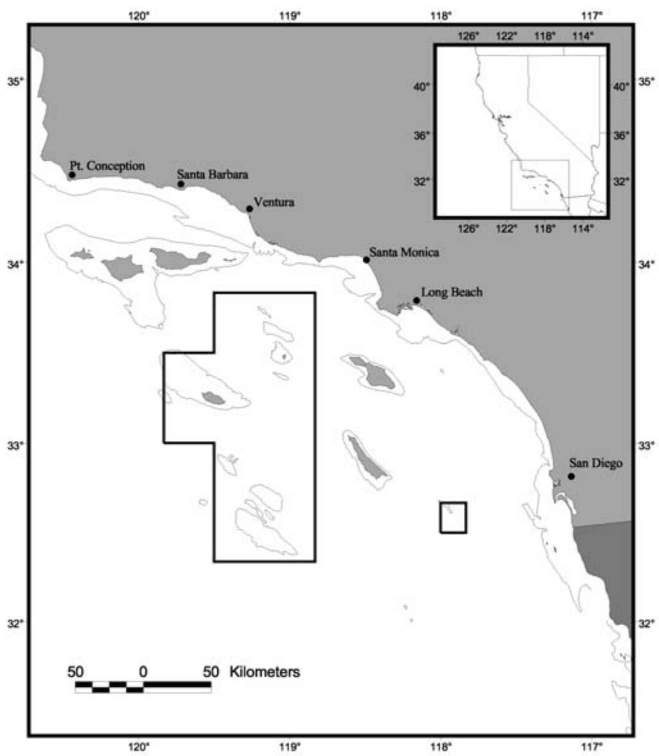

Fig. 8. Location of Cowcod Conservation Areas in the Southern California Bight.

Assessment of the effectiveness of these closures is underway. Baseline population surveys are being conducted inside and adjacent to these closures and the protocol for follow-up monitoring is being established. Without these, it will be impossible to determine what, if any, changes occur in rockfish and lingcod populations either within or outside these refuges.

Adult rockfish and lingcod populations, in particular, are very difficult (or impossible) to accurately appraise with traditional survey methods such as the use of surface-based trawl gear. This is because trawl nets are virtually excluded from high-relief rock outcrops, which are precisely the habitats where many rockfishes and lingcod (and often the larger individuals of the population) are most abundant (Yoklavich *et al.* 2000). Consequently, alternative techniques are necessary to track the recovery of these fishes.

In collaboration with researchers from University of California Santa Barbara, Moss Landing Marine Laboratories, and California Department of Fish and Game, and with additional funding from NOAA National Undersea Research Program, NOAA Center for MPA Science, and the David and Lucile Packard Foundation, we are conducting underwater surveys of rockfish populations and their associated habitats over rocky banks inside and in the vicinity of the newly established Cowcod Conservation Areas using *in situ* video-transect techniques and direct observations from an occupied research submersible. We are using quantitative transect techniques to estimate abundance and fine-scale distribution of habitats and fish density, size structure, and species composition and richness. These variables will be analysed relative to depth and microhabitat, and compared between areas in and out of the MPA. Digital, georeferenced maps of the seafloor, acquired from side-scan sonar, multibeam bathymetry, seismic reflection and other past geophysical surveys, are being used together with past and recent groundfish catch-and-effort records to identify and select sites with appropriate habitats. We strongly believe that the success or failure of the MPA will depend on the timely and accurate assessment of its effectiveness. But, before we can assess whether the CCAs are effective in rebuilding these fish populations, we need to (*1*) accurately estimate the abundance of rockfishes and lingcod near the onset of MPA establishment, (*2*) identify the locations of remnant populations of these target species outside the CCAs and evaluate these sites for additional protection, and (*3*) appraise the status and use of the protected benthic habitats by target fish species currently designated as severely overfished.

Our study sites and survey protocols will serve as the foundation for a long-term monitoring program for the CCAs as well as a model for monitoring future deepwater MPAs, which are currently being developed under California's *Marine Life Protection Act of 1999* and are being considered by the Pacific Fisheries Management Council's Marine Reserve Advisory Panel (Parrish *et al.* 2000). Results of our studies will also be particularly useful in producing more accurate stock assessments for those fishes associated with high-relief rock habitats, especially those southern California species that presently are not assessed. This information is essential in monitoring the effectiveness of those programs designed to rebuild these overfished stocks.

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MUST AQUATIC PROTECTED AREAS BE 'ALL AT SEA'? MAKING THE MOST OF WHAT WE ALREADY HAVE FOR 'TERRESTRIAL' AQUATIC PROTECTED AREAS

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Abstract

Success stories of marine protected areas (MPAs) are rarely matched for 'terrestrial' aquatic systems, despite widespread appreciation of their values, the pressures they face, and the sense of urgency with which we need to address their conservation. Drawing on recent Australian experience with the Ramsar Convention, this paper examines some of the possibilities and challenges of using the Convention to accelerate and strengthen a comprehensive, adequate, and representative system of aquatic protected areas. The paper expresses concern that development of such a system in Australia appears to be marked by competitiveness rather than by cooperation.

Keywords: Ramsar, wetlands, collaboration, partnership, Federalism

INTRODUCTION

The depth and breadth of attendance at this Congress demonstrate a widespread appreciation of the importance of developing systems of protected areas for aquatic ecosystems, and also of the challenges in achieving this outcome. Many other papers at this Congress will detail issues with marine protected areas (MPAs). The Congress Abstracts show that we are still debating longstanding issues such as the basis for selection, the management of use, and the scientific basis of both sets of decisions.

Whilst many of the same debates continue in relation to protected areas on the Australian continent, it is clear that after decades of conservation efforts we have come a long way in developing widespread acceptance of the need for protected areas as a primary conservation tool (Figgis 1999). This has tended to operate at several different levels over time. In just a few decades we have witnessed a shift from setting aside areas valued primarily for their scenic and recreational value (amenity), through preserving places for appealing plants and animals (species), to conserving particular communities such as rainforests (ecosystems). But through all of these the predominant tool used was a 'locking up' of the land or, rather, a 'locking out' of uses that were seen to be incompatible.

In more recent times we have seen much greater recognition of the importance of all species and all ecosystems. As the concept of biodiversity has entered the language, we have been seeing protected areas pursued in the interests of the somewhat less attractive species and ecosystems, even targeting 'the other 99%' of biodiversity in the invertebrate world.

For terrestrial ecosystems this approach has brought conservation down from steep and rugged terrain and out of impenetrable vegetation communities – those islands of nature that could not be used for anything else – to compete directly with commercial uses in grasslands, on rich river flats and even in the midst of urban areas. This has led to a gradually increasing (but at times begrudging) acceptance that conservation of biodiversity will not be achieved solely by permanent setting aside of isolated national parks and nature reserves, and will not always be well served by removal of humans from what are essentially cultural landscapes. Under economic rationalism we will never be able to meet the cost, and will never have the capacity within management agencies, to achieve the objectives through this single modality. Rather, we need to pursue sustainable management objectives on a wide range of public and private-tenure lands, and through a wide range of people engaged in different uses of those lands, some for their sustenance and livelihood.

In a corollary to this we are also seeing a shift beyond the amenity, species and ecosystem levels to pursuit of conservation objectives at bioregional and landscape scales, recognising at last the seamlessness of the natural world and the complexity of human ecology. It may seem somewhat surprising then that development of protected areas for aquatic systems, one of the most obviously seamless components, has lagged behind. At the same time as approaches to MPAs have caught up with those for their terrestrial counterparts, or possibly because of that development, we are becoming aware that terrestrial approaches are not adequately addressing conservation of aquatic ecosystems.

Unfortunately, much of the debate over sustainable management of these systems has become clouded by arcane approaches to what is not intrinsically different from conservation of other elements of terrestrial landscapes, and therefore not particularly difficult. In this cloud we are at risk of losing our way. Our ability to use tools already at our disposal is obscured by obsession with the new.

THIS RAISES TWO KEY QUESTIONS:

- What would be the characteristics of an effective system of aquatic protected areas (APAs)?
- What do we already have that could be applied <u>now</u> to address conservation needs?

I suggest that characteristics of an effective system of terrestrial APAs, incorporating fresh and saline inland waters, in the vast Australian jurisdiction might involve

- *comprehensiveness* – taking a 'whole landscape' approach to types, encompassing aquatic systems from the obvious (e.g. open waters in lakes and watercourses) to the occult (e.g. groundwater aquifers and karsts), from permanent to ephemeral, from alpine to coastal and shallow marine, from tropical north to sub-Antarctic south and from Norfolk Island in the east to the Cocos (Keeling) Islands in the west;
- *representativeness* – stratifying and characterising in a systematic way to encompass what we know of biogeography and landscape dynamics;
- *adequacy* – using a reasoned basis for assessing values, how large or how connected the areas need to be, and how best to manage them to conserve those values, including 'whole catchment' approaches capable of taking into account cryptic groundwater hydrology; and
- *constituency* – ensuring broad stakeholder support for sustainable management of a range of values, and active engagement in assessment, planning, management and monitoring of effectiveness.

At the highest level, such characteristics are self-evident and are quite within reach. Why then are we so far from achieving this kind of result? I contend that one major factor that has tended to confound wide acceptance of these principles is a historic tendency for each level of government to seek to retain control of water at the expense of neighbours and the national good. Until some very recently achieved water reforms, this kind of picture made landscape approaches difficult, and national consistency and cooperation close to impossible.

During that quite extended period, a perception has arisen of rifts and tensions between and within two starkly painted groups – 'the plumbers' who deal with reticulation and commercial value of water and 'the biologists' who deal with environmental flows and natural values. All of this provides fertile ground for a diverse range of stakeholders to be acting at cross-purposes, working in competition, rather than in cooperation, with each other – despite the short time that remains to secure the sustainable management of what remains of aquatic systems.

Regardless of how sceptical we might be of the validity of such perceptions, the parties do not seem to be able to agree on the frameworks and tools that we need to use for an effective system of APAs. Each contesting party will seek to push their own new technique, solution or brilliant idea, believing that the other parties have got it all wrong and need to be defeated. In the meantime, aquatic ecosystems are continually being placed at risk. It's all a bit like saying, 'It's your end of the boat that is sinking'.

I contend that we actually have frameworks and tools already at hand that could allow us to be getting on with the cooperative task of conservation of aquatic ecosystems, instead of butting heads. What is more, we have had access to these tools for some decades.

Australia was one of the first Contracting Parties to the Convention on Wetlands of International Importance signed at Ramsar, Iran, in 1971. The stated mission of this Convention is the 'conservation and wise use of wetlands by national action and international cooperation as a means to achieving sustainable development throughout the world' (Ramsar CoP6 1996).

This paper will recap what devices the Ramsar Convention offers, and draw on Australia's national report to the Conference of Parties (Commonwealth of Australia 2002) to assess how well we have deployed these, and what forces are working against them. It will then examine some directions in which we could profitably be heading.

Detractors of the Ramsar Convention sometimes portray it as too narrow to deal with aquatic ecosystems more generally, misrepresenting the scope of wetlands as being limited to 'ponds with reeds' or 'mangrove swamps'. Rather, the definition of wetland is quite broad enough to encompass the full range of terrestrial aquatic ecosystems: 'areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres' (Ramsar Convention Bureau 2000). The latter enables inclusion of intertidal mudflats, or even lagoons and shallows associated with coral reefs.

Converse arguments that this is just too broad to comprehend or to communicate are missing the point that however diverse the types of aquatic ecosystems may be, consistent values are attached and there are fundamental principles to be followed to conserve those values. The Ramsar Convention acknowledges the ecological functions of wetlands as regulators and as habitats, linking these to their economic, cultural, scientific, and recreational values. In recognition of the dramatic rate of loss of, and encroachment on, these kinds of systems, it fosters active management to ensure their 'wise use', a concept enshrining sustainable use and inter-generational equity (Ramsar Convention Bureau 2000).

The Convention thus provides a valuable global context for sustainable management of aquatic ecosystems, bolstered by a joint work plan with the Convention on Biological Diversity and memoranda of cooperation with the Conventions on Migratory Species, World Heritage and Desertification. This connectivity and synergy are about to be extended further with functional links to other conventions and with the forthcoming World Summit on Sustainable Development.

Although its membership comprises governments, the Convention models the importance of intersectoral collaboration by recognising international NGO partners, including IUCN, Bird Life International, the World Wide Fund for Nature, and Wetlands International. In turn, it encourages Contracting Parties to collaborate with the non-government and industry sectors.

CONTRACTING PARTIES TO THE CONVENTION ARE OBLIGED TO:

- promote as far as possible the wise use of wetlands through their territory,
- designate sites to the list of wetlands of international importance ('the Ramsar list'),
- establish conservation reserves to protect wetland values,
- promote training in research and management of wetlands, and
- consult with other parties in wetland management.

This is no small undertaking and yet there has been no shortage of takers – as of 9 August 2002, 133 nations were Contracting Parties, and the Ramsar list contained 1180 sites totalling 103.2 million hectares (http://www.ramsar.org). For its part, Australia has 57 sites listed, totalling some 5.3 million ha. After more than thirty years, new nations keep signing up and new sites keep being added to the list – the Convention really must have something tangible to offer.

So let us return to what devices it may offer to assist a system of terrestrial APAs in Australia. In terms of the characteristics identified previously, the Convention (Ramsar Convention Bureau 2000) actively promotes principles of comprehensiveness, adequacy and representative-ness, and offers a range of frameworks and tools to

- improve institutional and organisational arrangements,
- address legislation and government policies,
- increase knowledge and awareness of wetlands and the full range of their values,
- review the status of, and identify priorities for, all wetlands in a national context, and
- address problems at particular wetland sites.

Examples of specific guidance under these include tools to:

- develop and implement national wetland policies,
- integrate wetland conservation into river basin and catchment management,
- prepare management plans,
- conduct impact assessment and monitoring programs,
- engage local communities and indigenous people in wetland management, and
- involve the private sector in conservation and wise use of wetlands.

The devices offered are subjected to continuous review and improvement through international panels and working parties, ensuring a high and increasing level of scientific and technical rigour.

BUT HOW DOES 'WISE USE OF ALL WETLANDS' EQUATE WITH DECLARING AND MANAGING APAS?

In this consideration the definition of a protected area is taken to be 'an area of land and/or sea especially dedicated to the protection and maintenance of natural and associated cultural resources, and managed through legal or other effective means' (IUCN 1994). This form of words suffers from the incessant challenge of communicating that water is part of 'land', made more complicated by some 'terrestrial' protected areas that contain marine components and some 'marine' protected areas that contain terrestrial components (Cresswell and Thomas 1997). This semantic issue for 'protected areas' is actually quite well addressed by the Ramsar definition of wetlands.

Our belated recognition that conservation occurs across a spectrum is reflected in the range of categories of protected area used by IUCN. These range from Category 1a, which represents a 'single use' strict conservation reserve, to the more recently defined Category VI, which represents multiple use carried out in such a way as to ensure sustainable management of values (Cresswell and Thomas 1997).

This spectrum is entirely compatible with the Ramsar Convention's wise-use approach and with the kind of zonation it encourages in management planning. Similarly, both IUCN and Ramsar emphasise the active engagement of local and indigenous communities in shaping and implementing management plans.

I simply do not accept that 'wise use of all wetlands' is incompatible with the kind of priority setting inherent in assessment, selection and management of APAs. In both frames comprehensive assessment of aquatic ecosystems across a bioregion, administrative region or catchment would indicate (and perhaps weight) a range of values and threats, and a corresponding set of priorities for conservation effort and investment, suggesting a range of conservation mechanisms available under both federal and State/Territory legislation and policy regimes.

TO RECAP, THUS FAR AN APPRAISAL OF WHAT THE RAMSAR CONVENTION HAS TO OFFER SUGGESTS THE FOLLOWING:

- the scope of the Convention is not inappropriate in terms of the definitions of wetlands and protected areas, nor in terms of the categories of protected areas;
- the Convention's emphasis on 'wise use of all wetlands' is entirely consistent with informed and balanced approaches to conservation in multiple-use environments;
- the Convention encourages and provides devices to support all the important characteristics of a system of APAs;
- the approach of the Convention is compatible with a wide range of international, national and regional strategies, policies, agreements and arrangements;
- the approaches and devices offered by the Convention are subject to continuous review and improvement underpinned by scientific and technical rigour;
- as a nation Australia is already contracted under the Ramsar Convention to meet certain obligations, including the wise use of all wetlands; and
- Federalism implies that these obligations are shared between federal and State/Territory governments – the Convention already applies at all levels.

With such a high degree of applicability to the Australian situation, and after 30 years as a Contracting Party, one might expect Australia to be achieving highly on all the expectations of the Convention. However, perusal of our national report to the Ramsar Conference of Parties suggests that, despite some laudable achievements, we collectively have a long way to go.

In the area of legislation, policies and institutions, the news was not all bad, citing

- introduction of statutory protection for Ramsar wetlands and habitat of listed migratory waterbirds under the EPBC Act along with new standards for managing Ramsar wetlands ('Australian Ramsar management principles'),
- development of wetland policies in half the States and Territories, and with draft policies for the remainder,
- progress in water reform in all States and Territories, designed to provide water for the environment including wetland ecosystems,
- substantial investment of federal funding for a variety of wetland rehabilitation and conservation projects, largely being implemented by community groups,
- development of new directions for wetland site management involving community, indigenous and private-sector groups in site monitoring, and
- emergence of new partnerships between corporate/private-sector and non-government conservation organisations to deliver wetland conservation and rehabilitation projects.

Under 'conservation of Ramsar sites' and 'designation of new Ramsar sites' it was not so good, indicating

- a significant lag in preparation or updating of management plans, with no plans in place for one-third of the 57 listed sites, and only 8 of these 19 in progress,

- a degree of inadequacy and inconsistency in description of ecological character in Ramsar Information Sheets and in management plans, with flow-on implications for managers' ability to monitor and report on-site condition,
- four new Ramsar sites designated and five existing Ramsar sites extended since the previous Conference of Parties in 1999, and
- some systematic assessment of candidate Ramsar sites carried out in Western Australia, but conspicuously in no other State or Territory.

At the national level perhaps the most innovative step taken was recognition of wetlands designated to the Ramsar list as matters of national environmental significance under the *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act). This has the effect of requiring the approval of the Commonwealth [Australian federal] Environment Minister for an action that has, may have, or is likely to have, a significant impact on such a wetland. That action does not have to take place in the wetland itself to fall within the ambit of the EPBC Act, allowing consideration of actions in the catchment of a wetland. There is an argument that the EPBC Act has been able to afford a significantly higher level of protection to some wetlands because these had been listed under the Ramsar Convention.

However, this regime was not extended to give legislative effect to our further obligation as a Contracting Party to promote as far as possible the wise use of all wetlands in our territory. The federal government is active in encouraging State and Territory governments, who carry the major responsibility for environment management, to pursue wise-use principles, but it is constrained by the current flavour of Federalism and is pushing at the limits of its Constitutional ability.

Some opportunities are offered in the shift to regional delivery of much of the federal funding for the Natural Heritage Trust and National Action Plan for Salinity and Water Quality. In principle this shift empowers regional communities to invest in management of their natural resources, including aquatic systems. With wetlands explicitly included in national goals and targets for biodiversity conservation (Commonwealth of Australia 2001) and in other documents that guide priorities for such investment, funding agreements may provide leverage with regional bodies to give effect to wise-use principles to a degree not previously achieved in funding agreements with States and Territories.

Perhaps the greatest opportunity offered by the shift to regional investment in natural resource management (NRM) is the impetus given to conservation at landscape level, across tenures, and through new coalitions and partnerships. This offers considerable potential for establishment and sustainable use of a system of APAs. We can only hope that this will not encourage even more competitiveness to hinder application of the frameworks and tools available to us under the Ramsar Convention.

The federal and State and Territory governments did cooperate to develop the national objectives and targets for biodiversity conservation for 2001–2005 (Commonwealth of Australia 2001). In addition to numerous objectives with indirect impact for aquatic systems, this document contained explicit targets directly relevant to obligations under the Ramsar Convention. This latter group included

- by 2001, all jurisdictions identifying wetlands of national and international significance and important areas of habitat for migratory waterbirds;
- by 2003, management plans for 85% of Ramsar-listed wetlands being prepared and implemented consistent with the Australian Ramsar Management Principles, and all jurisdictions having programs in place, both on and off reserve, to protect significant habitats for migratory waterbirds, and
- by 2005, all jurisdictions having effective legislation and management plans in place to protect wetlands of national significance; and the number of Australian sites in the East Asian–Australasian Shorebird Site Network increased from 11 in 2001 to 36.

The national report (Commonwealth of Australia 2002) cited some additional targets by 2005 for designation to the Ramsar list, being a total of 75 sites (including 10 in under-represented types such as coral reefs, seagrass beds, karsts and arid wetlands) across a wide geographic spread, and representing an increase in aggregate area of 30%.

These targets are all worthy aspirations and are readily achievable, except for a persistent theme throughout the national report. In something of a mantra, jurisdictions repeatedly cited lack of resources to carry out wetland inventory, management planning, monitoring, research, education and training.

One interpretation is that Ramsar obligations are seen as something that the federal government has undertaken and then imposed on States and

Territories. In this view, the federal government should be providing all the funds to implement or advance those imposed obligations. On the face of it, this might seem reasonable except that, having argued to retain responsibility for such matters, some jurisdictions did not appear to have afforded them priority in their own budgets, despite aspirational statements in their policy documents and strategies. It is acknowledged that agency budgets are sorely stretched in the modern climate. Even so, this would be misdirection – 'it is our responsibility, not that of the federal government, to manage such matters, but it is the federal government's responsibility, not ours, to fund such management'.

Any misrepresentation of the Ramsar Convention as a federal imposition could have deleterious effects in the shift of funding to regional NRM bodies. Unfortunately, the incorporation of designated wetlands as matters of national environmental significance in the EPBC Act may have helped to fuel efforts to engender fear of federal takeover among communities considering such a designation. There is anecdotal evidence of instances (even campaigns) of disinformation portraying the Convention as having only the one modality – designation to the Ramsar list – a convenient development for those who appear to see Ramsar listing as competition for their own schemes for protection.

A number of groups have emerged with a vested interest in making 'Ramsar' a dirty word among rural and regional communities – even dressing it up as a front for United Nations interference in the way private landholders manage their land and water. However, any objective appraisal would note the primary emphasis of the Convention on wise use, an approach that recognises all values and that benefits all stakeholders, including those who derive their livelihoods from wetland resources.

Misdirection of this sort could be effectively countered by a sincere and concerted effort by the scientifically and technically literate in our communities to redirect thinking and resources in appropriate proportions to the conservation and wise use of wetlands. But instead of being voices of reason, some denigrate the Convention's frameworks and tools as less scientifically rigorous than we might like, or as 'not quite appropriate' to Australia's or their own State's situation, or under some other construct, all of which in effect say, 'If it isn't perfect, let's not bother with it'. But regrettably, the perfect is the enemy of the good. We are not progressing anywhere near fast enough.

The last thing we need is multiple players competing to develop a better mousetrap. Because they see the devices that we already have as competition for their own, they work against their deployment, despite the threats we face and the short time we have to deal with them. In such a zero-sum game, the stakes are no less than the future of our aquatic ecosystems and the only guaranteed winners are the mice.

But I am actually much more optimistic than that. In my view, reasonable progress will be made when all jurisdictions, together with all sectors of the NRM community

- acknowledge the urgency we face in securing conservation of aquatic ecosystems and accept that we do not have the luxury of deferring action until we have 'the perfect system',
- accept that the Ramsar Convention offers a comprehensive and appropriate framework and set of tools to guide conservation and wise use of aquatic protected areas in a nationally consistent way – by no means 'perfect', but a solid foundation,
- accept that all levels of government share responsibility for national obligations under the Convention and redirect resources accordingly to support initiatives at both State/Territory and regional levels,
- eschew competition in favour of cooperation, bringing to bear all available modalities and all sectors, to meet shared objectives, and
- continue to refine and improve scientific and technical knowledge and skills to advance those objectives in association with our international peers.

We can, we will, and we must.

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MANAGING IMPACTS OF ADJACENT DEVELOPMENT ON AQUATIC PROTECTED AREAS: CASE STUDIES FROM THE TRINITY INLET FISH HABITAT AREA, NORTH QUEENSLAND

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Abstract

Fish Habitat Areas (FHAs) are declared under the Queensland *Fisheries Act 1994* to protect the natural capital, the habitats and ecological processes that are critical to local and regional fish communities and fisheries productivity. Although development activities are severely restricted within the boundaries of FHAs, declaration provides no direct control over potential impacts on the protected Area from external sources. FHA managers may use a number of mechanisms to ensure that FHA values are not compromised by impacts from adjacent developments, including

- use of other regulatory instruments,
- provision of advice and guidance to developers, planners and managers, and
- education programs.

In addition, the formal recognition of the importance of an area of fish habitat through FHA declaration may in itself influence the decisions of planners and managers regarding adjacent development. Case studies from developments adjacent to the declared Trinity Inlet Fish Habitat Area - which protects approximately 7 500 hectares of wetlands in Cairns, a rapidly growing regional city in far north Queensland, Australia - are presented to illustrate the challenges of managing off-site catchment impacts on aquatic protected areas. An option for establishing a formal network of stakeholders involved in catchment and estuarine activities is proposed to coordinate management issues across the different regulatory and planning agencies and community groups.

***Keywords**:* Trinity Inlet, fish habitat area, management, development, aquatic protected areas

FISH HABITAT AREAS

A Fish Habitat Area (FHA) is a spatially defined area of inshore or estuarine fish habitats, which contains values that are important to sustaining local and regional fish stocks and fisheries and is specifically protected under the provisions of the Queensland *Fisheries Act 1994* to ensure these values are maintained. FHA declaration offers all habitat types (e.g. vegetation, sand bars, rocky headlands) within its declared boundary an equal, high level of protection from physical disturbance or impacts (Zeller and Beumer 1996). FHA management recognises that the physical structure of the habitat as a whole contributes to the health of the environment and to fisheries productivity (Coles and Fortes 2001).

While an individual FHA is nominated and declared on the basis on its specific habitat and fisheries values, each FHA extends the Statewide network of Fish Habitat Areas. The Areas combine to help protect the regional viability of Queensland's fish, mollusc and crustacean stocks by supporting adjacent and offshore fishing grounds (via primary production inputs, protection of nursery areas and feeding grounds, and protection of spawning locations). Declared FHAs form an integral part of the total coastal planning process for future fish habitat protection and are gazetted following appropriate consultation (Beumer *et al.* 1997).

There are currently 74 declared FHAs distributed along the Queensland coast from Currumbin Creek near the Queensland / New South Wales border to Eight Mile Creek near Burketown in the Gulf of Carpentaria. These 74 FHAs cover an area of over

715 000 hectares of fish habitats (McKinnon *et al.* in press). FHAs have been declared across many estuaries, downstream of and subject to many of the impacts generated throughout a catchment. Only one Fish Habitat Area in Queensland includes freshwater areas within its declared boundaries. This is the declared Trinity Inlet FHA that includes approx 400 hectares of contiguous freshwater creeks and wetlands.

Trinity Inlet fish habitat area

Trinity Inlet lies adjacent to the City of Cairns in Far North Queensland, Australia. Cairns has a population of approximately 130 000 people and is a major international and domestic tourist destination (Lane 1999). The Inlet is an important harbour and port for commercial and recreational activities in Far North Queensland (EPA 1999). Trinity Inlet is unusual in that there is no major flows of freshwater into this large estuary. It is a tidally dominated system with only minor seasonal changes in salinity (TIMP 1998). The Trinity Inlet catchment is one of the smallest catchments in Australia in which a major population centre is located (Greening Australia 1996). The catchment is approximately 370 km^2 (Helmke *et al.* 2000).

Extensive mangrove and seagrass communities surrounding the Inlet are biologically very productive and maintain important commercial, recreational and indigenous fisheries (TIMP 1998). Trinity Inlet encompasses not only vast areas of wetland ecosystems, but also a large tourism and port facility and industrial and urban development.

The Trinity Inlet Fish Habitat Area covers approximately 7500 hectares of mangrove forests, seagrass and algal beds, tidal estuaries and freshwater creeks. This constitutes approximately 20% of the catchment. The dominant biological environments of Trinity Inlet are the estuarine habitats and the tidal flats. Blackman *et al.* (1999) state that there are about 900 hectares of intertidal flats that act as rich and important food resources for fish, prawns and wading birds. These flats include bare mud, bare muddy sand, algal mats and seagrasses and support a diverse and abundant benthic fauna: surveys of the mudbanks, mangrove forests and saltmarshes have recorded at least 57 species of molluscs and 55 species of crustaceans (FRC 1999).

There are approximately 800 hectares of seagrass meadows and 3600 hectares of mangrove forests within Trinity Inlet. Seagrasses mainly occupy the wide intertidal mud flats and sand banks fringing Cairns harbour up to Ellie Point, and on the eastern shore of Trinity Bay north-east of Bessie Point (Campbell *et al.* 2001). Of the 14 seagrass species found in north-eastern Queensland, 8 have been recorded in Trinity Inlet (Coles *et al.* 1993). Mangroves are the dominant biological feature of Trinity Inlet, fringing the estuary at all points except the rocky outcrops of False Cape and the retaining wall adjacent the Cairns Esplanade (FRC 1999). Twenty-five species of mangrove have been recorded in Trinity Inlet and Bay, with dominant species being *Rhizophora, Avicennia* and *Ceriops* species.

Helmke *et al.* (2000) identified 95 fish species from 46 families in Department of Primary Industries (DPI) surveys conducted between 1997 and 1998. Barramundi, blue and king threadfin and spotted or banded grunter were the target species most frequently caught. When the results are combined with previous studies (Blaber 1980; Coles *et al.* 1993; Clarke and Tyson *et al*. 1996) approximately 235 species of fish from 70 families have now been recorded in Trinity Inlet (Helmke *et al.* 2000). Many of the species recorded in Trinity Inlet are important as direct or indirect foods of commercially and recreationally significant species such as barramundi, grunter, salmon, mangrove jack, king salmon, flathead, trevally, whiting, queenfish and bream (FRC 1999).

Tagging and recapture data have recorded movement of fish within Trinity Inlet and between Trinity Inlet and nearby systems. This demonstrates the existence of vital links between freshwater, estuarine and coastal environments (Helmke *et al* 2000). The DPI surveys also found that mud crabs are resident within Trinity Inlet and can sustain the current level of fishing pressure (Helmke *et al.* 2000).

Fisheries Research Consultants (FRC) (1999) documents that the Trinity Inlet estuarine communities as significant at a sub-regional scale because the Inlet and Bay form a unique combination of fish habitat types and are significant nursery ground for many species.

Fish habitat area declaration and the Trinity Inlet management program

The initial biological resources survey of the Trinity Inlet and Bay, conducted in the late 1970s. (Olsen 1993), confirmed the high fisheries and conservation values of this section of the Queensland coastline. A Steering Committee in the late 1980s led to the development of the Trinity Inlet Management Plan (TIMP), which included among its objectives the declaration of the area as a Fish Habitat Area. Implementation of the Plan saw the commencement of the consultation process to declare key fish habitats under the provisions of the previous *Fisheries Act 1976*.

Trinity Inlet was first declared a Fish Habitat Area in 1989. It initially included approximately 3100 hectares of tidal wetlands and waterways (Beumer *et al.* 1997). In 1992, the Trinity Inlet Management Program initiated a public consultation process to extend the Trinity Inlet Fish Habitat Area. The Program was a local organisation comprising of the Cairns City Council, Cairns Port Authority, local stakeholder groups and Queensland Government representatives (Environmental Protection Agency, Department of Natural Resources and Mines, Department of Primary Industries – Queensland Fisheries Service) to achieve consistent management outcomes and to implement the Trinity Inlet Management Plan (TIMP 1999).

FHA consultation generally involves public and individual meetings, presentations, correspondence, media releases and preparation of an Area of Interest Plan and consultation literature. At least two opportunities for community and stakeholder input are provided as part of every FHA consultation process (McKinnon and Sheppard 2001). All FHA declarations attempt to engender community understanding of the values of fish habitats, create a sense of community ownership of their fisheries resources and provide a strong legal framework for their protection.

McKinnon and Sheppard (2001) state that the consultation undertaken by the Queensland Fisheries Service (QFS) is intended to inform the community and stakeholders of

- the fisheries and fish habitat values of the nominated area,
- the benefits and restrictions of FHA management, and
- the FHA management options available (A or B Management levels).
- The consultation also gathers information on
- existing and planned uses within and adjacent to the area,
- the suitability and acceptability of the proposed boundary locations and Management level/s, and
- the overall level of support for the proposal.

The consultation and declaration of the Trinity Inlet Fish Habitat Area were based around the Trinity Inlet Management Program. The consultation process involved a coordinated approach with the DPI-, QFS and the TIMP consultative committee. Although consultation involved negotiations with similar stakeholder groups and community members, the process differed from the usual process. Typically, FHA consultation involves at least two phases of consultation and negotiation and is driven and coordinated by DPI (McKinnon and Sheppard 2001).

The consultation process for the Trinity Inlet FHA declaration proceeded through a number of critical stages, driven by emerging issues, developments and key stakeholders. The critical part of the consultation that involved public and individual meetings concluded in 1996, and a submission was made to Parliamentary Council in 1997. The expanded Trinity Inlet Fish Habitat Area was declared in 1998 under the provisions of the *Fisheries Act 1994*.

Fish habitat area management

The QFS manages all declared FHA's in Queensland. Any proposed development-related activities that require works within, or alteration to, a FHA, must be assessed by the QFS in accordance with management policy. The outcome of this assessment will determine whether the proposed activity can proceed within the FHA (Beumer and Zeller 1997).

A FHA may be declared as either 'A' or 'B' management levels, or a combination of the two. The two-tiered management approach recognises that important fish habitats occur within locations

- where very strict FHA management arrangements can be achieved, and
- where the FHA management recognises that existing or planned uses of some Areas or their surrounds require a more flexible management approach.

Although normal community use and activities (including legal fishing activities) are not restricted by FHA management, any works or activities requiring the disturbance of habitats within a FHA require a specific permit under the provisions of the *Fisheries Act 1994*.

The Trinity Inlet FHA is a combination of both A and B management areas. This reflects the presence of core areas of habitat within the Inlet (e.g. Admiralty Island) where strict management can be achieved and where there is limited existing and proposed future development. It also highlights the possibility that the freshwater areas and areas directly adjacent to the city may require a more adaptable management approach. The B Management area reflects this and also acts as a buffer zone.

Adjacent development

Although development and impacts within a declared FHA are subject to statutory provisions, the declaration provides no control over potential impacts from external sources and outside the boundaries of the FHA. There are other mechanisms however that can be used to help ensure that the values of the FHA are not compromised from adjacent developments.

These mechanisms include

- use of other regulatory instruments
- provision of advice and guidance to planners, developers and natural resource managers
- education and awareness programs
- formal FHA declaration process
- ongoing liaison with catchment groups and landowners.

A coordinated approach for delivery of the FHA management is needed with both freshwater and estuarine stakeholders. The TIMP consultative model attempted to achieve this and present a coordinated approach to Trinity Inlet. The current management plan seeks to ensure coordination and integrated planning and management of the Inlet (TIMP 1999). The challenge for management is the protection of 20% of the catchment within the declared FHA from the impacts of activities carried out in the remaining 80%.

Development in the Cairns area

Development in Cairns and its surrounds has led to the degradation of tidal and freshwater wetlands and waterways (TIMP 1998). Within the past 60-70 years there have been major losses of fish habitats through removal of mangrove forests, claypans and freshwater wetlands for port and airport facilities, agricultural development and urban development (TIMP 1992). These losses are often linked with the exposure of Acid Sulphate Soils, for example at the East Trinity development site, and the failure to manage acid runoff that has led to further detrimental impacts on fisheries values of the Inlet.

As Trinity Inlet is close to a major population centre, the pressures on the fisheries resources are ongoing and extensive. These include pressure and competition between commercial, recreational and indigenous fishers and also downstream impacts from urban and agricultural expansion (Helmke *et al.* 2000). WBM Oceanics (1997) reported that the major pollutants in the estuary are sewage, urban storm-water run-off, boating-related discharges, shipyard discharges and agricultural runoff. Helmke *et al.* (2000) showed that water quality in the freshwater sites, in the upper catchment, are much more heavily affected by agriculture and urban development than the estuarine sites.

The existing development within and adjacent to the Trinity Inlet FHA includes aquaculture, sewerage, airport, dumps, port facilities, urban development, agricultural lands and drainage. A number of new developments are also underway or proposed adjacent to the FHA. These include the Cairns Port expansion or Citiport project, esplanade redevelopment, southern Cairns transport infrastructure project, development of the False Cape area and increasing urban development.

MANAGEMENT CASE STUDIES

1. Cairns Esplanade redevelopment

Negotiations with Cairns City Council during the Trinity Inlet FHA consultation process highlighted its need to allow future development of the Cairns Esplanade. Proposed development included the expansion of public parklands and associated facilities, the addition of a public swimming area or lagoon, and the establishment of paths along the esplanade foreshore. Negotiations resulted in a B Management area gazetted adjacent to the Cairns Esplanade with an additional buffer zone to allow future development in the Esplanade region.

Recent works along the Esplanade, including reclamation works for a lagoon and recreation area, required a Marine Plant Permit under the *Fisheries Act 1994* to destroy mangrove propagules. Potential impacts on adjacent seagrass meadows within the FHA resulted in extensive negotiations to reduce the area of the reclamation and the implementation of a suitable Environmental Management Plan (EMP). The process of identifying a suitable source of fill to create the reclaimed area considered various options, with a land-based source being chosen as opposed to pumping sand across the mud flats from a sand source further north. A Scientific Advisory Group (SAG) was established as an advisory forum for monitoring impacts and reviewing results of EMP monitoring. The SAG included government agencies, the Cairns Port Authority, the Cairns City Council and private consultants. Part of the agreed monitoring program was to visually observe any sediment plumes as a result of the sand deposition on the mudflats. Overall the SAG worked cooperatively and helped to minimise any potential deleterious effects on the adjacent seagrass beds and declared Fish Habitat Area.

2. Cairns urban waterways

The Cairns urban waterways have been cleared, reclaimed and modified for the past 60 years. Aerial photographs and reports from the 1930s show brackish and freshwater lagoons and marine and freshwater creeks that have been filled to allow for expansion and development. This alteration has caused a loss of natural wetlands, of flora and fauna, and of connectivity between marine and freshwater environments, and degradation of water quality. As the majority of the City of Cairns has been built on lands within 1 m of the High Water mark, inundation at king tides is common. Further modifications to remaining waterways to enhance localised flood mitigation are proposed.

Aware of the potential values of urban waterways adjacent to the Trinity Inlet FHA the Trinity Inlet Management Program initiated a study by QFS to identify the remnant fisheries values of the urban drainage waterways of Cairns. The Cairns Drainage Waterway Management Report (Clarke and Tyson 1996) listed around 47 fish and crustacean species and identified 20 marine plant species within the urban waterway of Cairns. The findings of this study provided Cairns City Council the basis with which to develop a Waterways Management Best Practices Guideline to incorporate best practice techniques to its current drain maintenance program.

Ongoing negotiations between the QFS and Cairns City Council have resulted in a standard management approach: vegetation is retained on one bank of all drainage waterways. This approach has also influenced the creation of a Local Government Code of Practice, 'Strategic Maintenance Permit'. The codified Strategic Permit sets out very specific criteria and guidelines that have to be adhered to when councils conduct their maintenance works, including drainage works (Mayer *et al.* 2000). These fish habitat management measures not only provide a consistent approach to local government maintenance but also mean that councils are only required to obtain a single permit for all their ongoing maintenance works. This arrangement also highlights the value of fish habitats and how to mitigate the relative downstream effects of these works. For example, in relation to drainage works, the Code states that in most situations only the marine plants from one side of a bank of a drain or waterway may be removed and/or disturbed. By retention of the remnant marine and riparian vegetation, these fisheries resources are being protected while meeting the flood mitigation objectives and public safety concerns.

DISCUSSION

The Trinity Inlet Management Program consultative model has merits in developing a coordinated approach for fisheries and fisheries management in the Cairns region. In its original committee form the Program included on its steering committee the mayors and local State politicians for the region, giving strong political support to its management directions. The original plan and agreement that included the initiative to expand and re-gazette the FHA were signed at the level of the State Premier. The TIMP process endorsed and facilitated the Trinity Inlet FHA consultation and declaration and coordinated negotiations among major stakeholder groups. Although this approach was less bureaucratic, negotiations were often protracted and at some stages were not focused entirely on the FHA objective. The TIMP program, and therefore the FHA consultation, tended to concentrate on the water quality and catchment-related issues rather than the specific fisheries objective of protecting fish habitats.

A continuing consultative program involving relevant Government agencies and stakeholders and including a commitment to research and monitoring will be necessary for the ongoing management and viability of the declared Trinity Inlet FHA.

The long-term benefits of declaring a FHA within and adjacent to a developing urban centre needs to be reviewed on a regular basis. Although the Area continues to meet the FHA selection criteria and FHA objectives at this time, Cairns is a tourism destination and major port, and therefore any additional growth and expansion is restricted to a very specific area. Regardless of this, the Trinity Inlet Fish Habitat Area is valuable and provides protection for important and critical fisheries habitats.

The process of declaration and subsequent management has identified the value of ongoing liaison with all stakeholder groups, including those undertaking activities or works outside the boundaries of the FHA. Retention of the valuable fish habitats and fisheries values in areas adjacent will depend on recognition, through planning instruments by local Council. Inappropriate land development and land-use that result in detrimental downstream impacts on these values need to be addressed at this local Council level. Direct involvement by fisheries management agencies in catchment planning and development activities is a critical, ongoing and mandatory role.

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ROLE OF MARINE PROTECTED AREAS IN THE MANAGEMENT OF THE AUSTRALIAN NORTHERN PRAWN FISHERY

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Abstract

The Northern Prawn Fishery (NPF) is Australia's most valuable Commonwealth fishery, with an average annual catch of about 8,000 tonnes, worth between AUS$100 and $175 million and now taken by 104 modern trawlers. The fishery survived the early history of overcapitalization/overfishing common to most prawn trawl fisheries during the 1970s and early 1980s, when up to 302 trawlers were operating. Since the mid 1980s, fishing effort has been greatly reduced through industry-funded buybacks, spatial closures to protect small prawns and their nursery habitats and severe reductions in the fishing season from the entire year to just over 4½ months. Fishers, managers, researchers and environmentalists now share the responsibility for managing the NPF through their positions on the Northern Prawn Management Advisory Committee (NORMAC). A common vision has evolved of pursuing ecologically sustainable development through ecosystem-based management.

The fishery has been highly innovative in addressing bycatch issues and also has established a large system of "fishery closure areas" to protect juvenile prawn stocks, comprising about 8.7% of the NPF-managed zone. The NPF is working with government agencies and other stakeholders to develop a system of "no-take" marine protected areas in northern Australian waters that will both ensure biodiversity conservation and protect nursery and other habitats important to the sustainability of the prawn fishery. The research program to support ecologically sustainable development in the NPF includes research on assessing the status of the target stocks, bycatch and the impacts of trawling on animals in the soft sediments. The potential benefits to the fishery from marine protected areas are summarized.

Keywords: MPAs, Northern Prawn Fishery, critical nursery habitat

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THE FISHERY MANAGEMENT REGIME

Australia's Northern Prawn Fishery is based on nine commercial species of prawn (i.e. shrimp): white banana (*Fenneropenaeus merguiensis*), red legged banana (*F. indicus*), brown tiger (*Penaeus esculentus*), grooved tiger (*P. semisulcatus*), giant tiger (*P. monodon*), blue endeavour (*Metapenaeus endeavouri*), red endeavour (*M. ensis*), western king (*Melicertus latisulcatus*) and red spot king (*Mel. longistylus*). Banana and tiger prawns account for the majority of the landed catch in the fishery (banana prawns being the equivalent of 'white shrimp', and tiger prawns 'brown shrimp').

These targeted prawn species have a life span of up to two years. Juvenile prawns live in mangrove estuaries and the seagrass beds in estuaries and shallow coastal waters. After one to two months on the nursery grounds, the prawns move offshore into the fishing grounds. Whereas banana prawns reach commercial size at about six months of age, tiger prawns usually are required to be larger for the market, reaching their best commercial size at around nine to twelve months of age.

The Northern Prawn Fishery was established as a direct result of exploratory studies carried out by marine researchers during 1963–65. Although it is now regarded as one of the pacesetters in fisheries management in Australia, this reputation was not achieved without problems and controversy. Like many of the world's commercial fisheries, rapid development led to excess effort and over-capitalization. The fishery has had to accept severe management measures and intense restructuring of the fleet.

However, the benefits of effort-reduction measures have been partially offset by significant technological advances and the increased experience of the fleet (collectively called "effort creep") leading to greater fishing efficiency. Another significant issue has been the time required to reach agreement on restructuring measures and then to go through an open public process to legislate the changes into the management plan, which until recent administrative changes took at least 18 months.

The fishery is managed by the Australian Fisheries Management Authority (AFMA), which is the national fisheries management agency, under the Northern Prawn Fishery Management Plan 1995 through a combination of input controls. These include limited entry, temporal, seasonal and permanent area closures, restricted seasons, gear restrictions and operational controls. There are currently 104 boats active in the fishery. Fishing is permitted during two periods each year. In 2002, the fishery opened 1 April to 13 May and 1 September to 1 December, a period of only 135 days. These dates have been selected to minimize fishing effort on spawning stocks of the target prawn species, which spawn at different times of the year.

A notable feature of AFMA-managed fisheries is the recognition that a partnership approach is needed to achieve successful fisheries management. A Management Advisory Committee (MAC) is established for each fishery to provide a forum where issues are discussed, problems identified and possible solutions developed. MACs are expertise based and advisory in nature, and make recommendations on management and operational issues. Where AFMA believes that a MAC is performing well, it may delegate substantial responsibility for management planning for the fishery to the MAC, although it retains the power to ensure that MACs operate within the ecologically sustainable development (ESD) policy framework determined by AFMA.

This has allowed the Northern Prawn Management Advisory Committee (NORMAC) to develop as a direction-setting team that has moved away from the traditional sector-based approach to fisheries management and begun implementing ecosystem-based management of the fishery. There have been two key factors in this major paradigm shift. Firstly, for some years there has been an effective mix of experience and expertise in the membership of NORMAC, which includes fishing industry leaders, managers, scientists and environmentalists. Secondly, the willingness of NORMAC to rapidly translate the results of the latest research into improved fishery management measures has accustomed the industry to accepting changes in the management regime when they are needed.

PROTECTING CRITICAL NURSERY HABITAT

Currently, all known critical nursery seagrass areas for juvenile prawns in the NPF are protected from trawling under the NPF Management Plan in what are called Fishery Closure Areas. Continuous video monitoring satellite surveillance ensures that the closures are protected from trawling. There is 15,830 sq km of juvenile prawn habitat that mostly could be fished but is now protected within permanent closure areas, and a further 51,470 sq km protected within seasonal closure areas. These amount to 2% and 6.7 % of the NPF-managed area respectively. It is to the NPF industry's credit that such extensive areas of prawn habitat are protected from NPF fishing, but these areas are not protected from other human activities, including other forms of fishing.

Although most of the northern Australian coastline is only sparsely settled there are a number of land uses that can affect marine ecosystems adversely, and even severely. These include the construction of dams across coastal rivers, small-scale but extensive alterations to natural drainage to improve pasture ('ponded pasture'), bunding of tidal areas to prevent tidal inundation and thus create non-tidal pasture, and direct clearing of tidal wetlands (particularly tidal marshes and mangrove forests) in order to provide port-associated facilities or other dry-land uses. Substantial mineral development is planned or underway in the catchments of northern Australia and this could result in the release of contaminants into waterways.

In the marine environment, other users include oil and gas exploration and production, port developments, at-sea loading of minerals, recreational and other commercial fishers and indigenous communities. Proposals for future large-scale mining of the seabed for diamonds are of concern, as well as the potential for the introduction of marine pest species into the nursery grounds.

At present, the extensive mangrove forests, which provide critical nursery habitat for the NPF banana prawn fishery, are not protected within reserves.

NORMAC has attempted to establish a dialogue with other interests who may directly or indirectly affect the marine environment within the NPF-managed area and to provide scientific expertise to help the NPF minimize the impact of its activities. The NPF also hopes to contribute to the regional marine planning effort for northern waters foreshadowed in Australia's Oceans Policy, as well as assist Environment Australia in its investigations of the value of establishing marine protected areas for the extensive seagrass beds of the Gulf of Carpentaria.

The NPF has recognized that "No Take" marine protected areas are an important management tool that can benefit the fishing industry by providing greater protection to critical nursery habitat than can be provided by NPF legislation, as well as providing refugia for many of the benthic and bycatch species affected by NPF trawling.

The NPF now has a significant research effort underway to identify benthic species assemblages, model the performance of existing spatial closures, and identify different reserve configurations that can fully achieve biodiversity conservation objectives, while at the same time maximizing the value of the commercial fishery.

PRESSURES AND THREATS FROM WITHIN AND ADJACENT TO THE GREAT BARRIER REEF WORLD HERITAGE AREA

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Abstract

The Great Barrier Reef (GBR) was listed as a World Heritage Area (WHA) in 1981 on the basis of its unique biological, ecological and aesthetic values. The World Heritage Convention urges all state parties to do their utmost to ensure that the natural heritage of an area is conserved, protected, presented and transmitted to future generations. However, increasing pressures and threats from both within and outside the GBR are placing parts of the system, and potentially the entire system, at risk. These range from global threats such as climate change and coral bleaching to local threats such as land-based sources of pollution and seafloor trawling. The Australian State of the Environment Report 2001 found that Australian reefs were 'lucky' during the 1998 global bleaching event, with only 3% of reefs being lost. The GBR suffered a worse bleaching event in early 2002. More than 400 reefs are considered to be at risk along the developed catchments of the GBR coastline. Seafloor trawling is legally permitted throughout 50% of the GBR Marine Park. This damages the seafloor of the WHA and results in significant bycatch, raising questions about its consistency with the conservation and protection of the area's natural heritage. This paper describes the two key local threats which WWF considers are having a significant impact on the GBR – land-based pollution and prawn trawling – and concludes with recommendations to mitigate these threats in order to ensure that management is consistent with the World Heritage Convention and community expectations.

Keywords: Great Barrier Reef; World Heritage Area; land-based sources of pollution; trawling; coral bleaching

INTRODUCTION

The Great Barrier Reef (GBR) is unique. It is the world's largest and most complex expanse of living coral reefs (GBRMPA 1981), the largest Marine Park, and the largest World Heritage Area (WHA). But there's more to the Reef than size. The GBR supports the most diverse ecosystem known to humanity [GBRMPA, unpub]. There are more than 2900 coral reefs, about 940 islands and cays, about 350 species of hard corals and one-third of the world's soft corals. There are 1500 species of fish and many animal groups including sponges, anemones, marine worms, crustaceans, molluscs and echinoderms. It also contains one of the world's most important dugong populations and six out of seven of the world's threatened turtle species and spans 2300 km of coastline and covers about 348,000 km^2.

The GBR is also of great cultural significance. About 70 Traditional Owner groups have connections to the Reef, and many maintain a 'living culture' through use, practices and custodianship (GBRMPA 2002). At a national level in Australia, the GBR is a national icon. To damage or degrade it is socially unacceptable.

The Reef and its associated ecosystems (such as mangroves, seagrass meadows and tropical islands) are of exceptional natural beauty. This, along with its extraordinary biological diversity was recognised by World Heritage listing in 1981. Its underwater seascapes have inspired art, fashion and passionate environmental advocacy.

The GBR is integrally related to its adjacent catchment: "the Great Barrier Reef, its lagoon and the adjacent coastal watershed are a single ecosystem"(Sturgess 1999). As Sturgess warned, "with more intensive use of the coastal watershed and growing awareness of the cumulative impact on the reef of land-based activities, pressure to manage the region as an integrated ecosystem has already begun to grow. This pressure will continue." (Sturgess 1999).

This paper will look at the threat of land-based pollution of the GBR and ways that such pressure can be substantially reduced. It will also look at threats within the WHA such as seafloor trawling. It will present an argument for phasing out seafloor trawling and will suggest alternative ways forward.

CLIMATE CHANGE

The future of the GBR – and reefs around the world - is threatened by climate change. So far, the GBR has been relatively 'lucky', in that significant mortality of reefs from bleaching has not yet occurred. In 1998, inshore reefs of the GBR were extensively bleached. Four years later, the GBR suffered another bleaching event, from January through to March 2002. Inshore reefs were again extensively bleached, but this time offshore reefs were extensively but not uniformly bleached. According to the Intergovernmental Panel on Climate Change, bleaching events are expected to become more frequent and more severe. In its Third Assessment Report (2001), the Panel spelt out a grim picture for the GBR: reef death or damage from coral bleaching was considered a medium-to-high certainty in the next 20–50 years (Pittock and Wratt 2001).

With forecasts of this kind, it is imperative not only that we make rapid and deep cuts to greenhouse emissions, but that we do everything in our power to reduce other threats to the GBR. Although climate change needs both domestic and global action, other threats are local and well within our jurisdiction to solve. Of particular concern are land-based pollution of inshore reefs and seafloor trawling.

LAND-BASED SOURCES OF POLLUTION

The GBR catchment covers 370,000 km^2 and ranges from the tip of Cape York Peninsular to the Burnett River catchment just north of the Fraser Island World Heritage Area. Of the catchment, 77% is occupied by beef cattle grazing, whilst intensive cropping, mainly of sugar cane, dominates the low-lying coastal zone in the Wet Tropics, Whitsundays and Burnett River catchments. Fruit and vegetable growing and aquaculture are significant land uses in terms of per-hectare off-site pollution. However, these industries are not as spatially extensive as cattle or cane growing; hence, their impacts are not as great. Pollution from urban areas is locally significant.

The CRC Reef Research Centre and Great Barrier Reef Marine Park Authority (GBRMPA) have identified inshore reefs and seagrass communities from south of Cooktown to the southern boundary of the Marine Park as at risk from land-based pollution. This affected area includes 438 inshore reefs and 462 km^2 of seagrass beds. Reefs most at risk lie between Port Douglas and the Hinchinbrook Island region and from Bowen to Mackay (including the Whitsundays).

Poor land-use practices have resulted in large volumes of sediment, nutrients and pesticides flowing from rivers and creeks during the wet season into the inshore waters of the WHA. Land clearing, stock access to streams, overgrazing, excessive or poorly timed application of fertilisers and pesticides, inappropriate drainage systems, destruction of riparian vegetation and drainage of wetlands are some of the actions that are resulting in annually increasing pollution loads in these waterways.

The good news is that over the past few years, community, industry and government awareness of these problems has been on the increase. A report released on World Environment Day by WWF Australia entitled *Clear?…or present danger?* put the issue firmly on the public agenda (WWF 2001). The GBRMPA has done an excellent job in progressing this critical issue. Now, both the Federal and the Queensland governments have committed themselves to finalising a joint Reef Protection Plan to tackle the water quality problem by the end of 2002.

This begs the question of what exactly we want from this Plan. Do we want to see the inshore waters of the GBR returned to the pristine conditions that occurred prior to land clearing and European agriculture? Who could say no, but it is almost certainly unachievable, given the inherent disturbance to land brought about by agriculture.

So what level of change is acceptable? On the basis of the existing scientific evidence, WWF suggests that the current level of change is already unacceptable and that we need to make serious reductions in pollution loads to allow degraded inshore reefs to start the process of rehabilitation. When we begin to see coral cover expanding, species diversity growing and coral recruitment levels becoming higher, then we can assume that inshore reefs are progressing towards an improved state. Until reefs show these signs of recovery over a sustained period, then WWF suggests that improvements to land management will continue to be needed. But the reality is that there is no end point when reefs will once again be as they once were and land practices will no longer need to change.

What should we do to bring about this progression towards increasing the diversity and beauty of these reefs? Firstly, WWF believes that the best policy response is based on risk assessment. It is great to see that this is the approach being pursued by GBRMPA. Seven catchments have been determined to be very high risk to inshore reefs and 19 others have been ranked according to lower risk categories. A GBR-catchment-wide policy response should be based on this catchment risk ranking.

Secondly, WWF supports the setting of end-of-river targets for each of the rivers adjoining the

GBR. Again, GBRMPA has done an excellent job in setting these targets with the year 2011 as the timeframe. Target setting should be extended upstream, and the end-of-river targets and timetable should become statutory in order to create the pressure on governments and stakeholders to achieve them.

Thirdly, WWF supports immediate measures to protect existing natural habitat in the GBR catchment. It is irrational for a government to fund on-farm revegetation or wetland restoration projects when the farmer down the road is clearing or draining his property. Governments must regulate to stop the loss of natural habitat first so that the public's money can be spent wisely on restoration.

Fourthly, a variety of different measures should be introduced to encourage the rapid and widespread uptake of improved farming practices. One very important measure is to change the rules for farmers' access to government funding at both a state and federal level. At present, farmers have access to a wide variety of funding support. WWF supports a comprehensive review of the full suite of these programs in order to alter the eligibility criteria. The implementation of approved property management plans that contain practical on-the-ground measures to reduce sediment, nutrient and pesticide runoff should become part of the eligibility criteria in the GBR catchment. If certain farming practices are degrading the World Heritage values of the Great Barrier Reef, it is only natural that farming in a World Heritage catchment should be expected to meet higher standards than elsewhere.

Finally, both levels of government should initiate a strategic, risk-based riparian revegetation program. Riverbanks in all the high-risk catchments should be given priority.

These issues will be discussed in much more detail in the second half of 2002, as the Reef Protection Plan takes shape. WWF will be very engaged with this process.

SEAFLOOR TRAWLING

I now want to turn to the other significant local threat to the WHA. When Gary Sturgess wrote in his Partnership report (1999) that "the development of the coastal watershed and water quality will be the central issues in the management of the GBR in the years ahead", he nevertheless wrote in the same sentence that "conflict over fisheries management will continue". It sounded as if he was annunciating an eternal law of the universe!

WWF Australia believes that seafloor trawling should be phased out of the Great Barrier Reef World Heritage Area. We have adopted this position because of evidence that seafloor trawling has a damaging and even destructive impact on areas of the seafloor that are repeatedly trawled. We are also concerned that vulnerable species are being severely depleted as a result of seafloor impacts and bycatch in trawl nets.

The World Heritage Convention imposes obligations on state parties to protect, conserve, present and transmit to future generations and, if appropriate, rehabilitate the outstanding universal value of listed properties. Activities that achieve these objectives should be promoted and activities that detract from these objectives should be avoided.

WWF believes the evidence is clear that seafloor trawling considerably detracts from the conservation and protection of the Great Barrier Reef and that phasing it out would provide the chance for damaged or degraded habitats and depleted populations of bycatch species to recover.

What is the evidence for our concerns? WWF Australia this morning released a report into the effects of seafloor trawling in the GBR. The report refers to the CSIRO study (Poiner *et al.* 1998) into the effects of trawling in the far northern section of the Great Barrier Reef. The CSIRO study found that some fauna are particularly vulnerable to trawling because they are easily removed from the seafloor and their populations are slow to recover. In repeatedly trawled areas, these species are at high risk of localised 'extinction'.

Other species are more resilient to the frequent disturbance caused by repeated trawling and these tend to become more dominant on the seafloor. These tend to be fast growing 'weedy' species. Thus, the composition of seafloor habitats changes to favour weedy species. Repeated trawling over a number of years can even lead to the irreversible loss of these seafloor habitats.

Tens of thousands of tonnes of marine life other than the key target species of prawns and scallops are caught in trawl nets every year. Most of these species die. Turtle populations, especially of the endangered loggerhead, have been severely depleted over the past four to five decades by trawling. However, turtle excluder devices are now mandatory in the WHA, as are bycatch reduction devices. However, bycatch reduction devices currently in use are not particularly effective. The toll on non-target marine life is still very high.

WWF appreciates the economic and social value of the trawl fishery that operates inside the Great Barrier Reef. Currently, there are about 550 trawl licences along the entire east coast of Queensland – a considerable number even after the structural adjustment program of 2001. Therefore, WWF is committed to finding ways in which people can remain employed and the Marine Park can be protected – in other words, substituting a damaging method of extractive use with a non-damaging method. In the meantime, we support further effort reduction, accompanied where appropriate by a structural adjustment package.

In July 2002, WWF received a copy of an Information Paper outlining two applications to the Queensland Fisheries Service for developmental fishing permits for prawn and bug trapping along the east coast of Queensland, one of them being for use in the GBR. In relation to the GBR application, the Paper states that “the applicant can see an environmentally friendlier way to harvest prawns and bugs than techniques presently being used”. The other applicant stressed that they can envisage a viable industry in the marketing of prawn-trapping apparatus.

WWF will be making a submission on this Information Paper and we congratulate the commercial fishers for their innovative applications. If their devices prove commercially viable and there are no obvious environmental problems associated with them, WWF would be seeking a transition by the whole of the industry to this new fishing method.

It may be that for some prawn species in some areas, marine prawn farming may be the only viable option for a transition out of seafloor trawling. Marine prawn farming has its own set of environmental issues, and strict standards would need to apply so as not to simply shift from one set of problems to another.

CONCLUSION

The GBR has been viewed as a robust ecosystem that has survived sea level rise, cyclones, massive floods and storms for many thousands of years. However, today, it must cope with all these natural events, plus a barrage of human-induced pressures as well. Increased sea surface temperature, increased storm events, land-based pollution of inshore reefs, overfishing or destructive fishing practices, coastal development, coastal population growth, increased frequency and severity of Crown of Thorns starfish outbreaks, and extensive tourism and recreational use are all pressures that 200 years ago the Reef did not have to bear. Under the weight of these pressures and threats, this naturally robust ecosystem is becoming increasingly fragile.

People from all around the world come to marvel at this unique ecosystem. We could lose it, but its value and beauty may save it. We have the methods now to reduce pollution, and governments appear willing to address this problem. We now have commercial fishers who are applying for permits to experiment with non-trawl methods. This heralds a new industry that could put little environmental pressure on the Reef and be transferred to other tropical prawn trawl fisheries in other coral reef eco-regions. With respect to climate change, our governments could do much more. There are major threats to the Reef but also significant new and positive developments, and overall a strong constituency of support in Australia for its increased protection.

I finish with a quote from a paper presented by Professor Jay O’Keeffe (O’Keefe and Schofield 2001) of Rhodes University, South Africa, at a national conference held last year in Townsville called Sustaining our Aquatic Environments. He said:

“Australia is a huge and enchanting continent, with vast and diverse environments and great natural resources. Australians are a vibrant and energetic nation, relatively few for the size of the continent, relatively well educated, and relatively affluent. If Australian can’t enhance the values and health of their aquatic environments, then there’s very little hope for the rest of the globe!”

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USE OF ECOSYSTEM MODELLING FOR THE EVALUATION OF MARINE PROTECTED AREAS: THE NORTHERN GREAT BARRIER REEF AS A CASE STUDY

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Abstract

The ECOPATH EwE software platform was used to model and simulate the temporal and spatial reactions of the far-northern Great Barrier Reef (GBR) ecosystem to a Marine Protected Area (MPA). Temporal and spatial simulations used data from commercial trawl and line fisheries that operate within the GBR World Heritage Area. The base GBR model grouped research-survey information on the distribution, abundance and diet of more than a thousand fish and non-fish species into 25 trophic guilds. Using this model a series of MPA scenarios were simulated for the far northern GBA, ranging from nil fisheries compliance through to complete compliance with the cross-shelf area closure. Results suggested that the addition of spatially explicit habitat data to the equilibrium GBR ecosystem model (with no MPA) significantly buffered the predicted volatility in trophic-guild biomass, by providing "*de facto*" spatial refugia from fishing pressure. Scenario simulations at varying levels of compliance showed that MPAs must be of adequate size to allow for "edge effects" caused by illegal fishing, particularly if sited in remote areas. Fishing tended to concentrate on borders of the MPA, which would produce "gauntlet" effects to the movement of some groups. Vulnerable species did better within an MPA, but scavenger/opportunistic species did worse. The underlying mechanism determining the effect of a MPA on these species groups can be described from Connell's Intermediate Disturbance theory.

Keywords: intermediate disturbance, fishing cascade

INTRODUCTION

A Marine Protected Area (MPA) is usually set up as representative of a habitat type or bioregion that has unique conservation values, and/or to ensure undisturbed recruitment or replenishment for commercial, recreational or endangered fish species. An example of the purpose of such MPAs is to ensure the conservation and sustainability of the multi-species assemblage within that particular area. Evaluation of the effectiveness of potential and existing MPAs requires tools that are sophisticated enough to describe the likely impact an MPA has on a complex interrelated web of species. Ecosystem models provide such a tool, particularly if these models incorporate spatial information.

In this study an existing ecosystem model of the northern Great Barrier Reef (Gribble 2000) was used as a tool to evaluate Great Barrier Reef Marine Park far-northern cross-shelf area closure, established by the Great Barrier Reef Marine Park Authority (GBRMA) in 1985. This Area Closure is a large (10,000 sq nmiles) MPA that has been extensively surveyed as part of an "Ecological Effects Of Trawling on the Far Northern Great Barrier Reef" research project (Poiner *et al***.** 1998). As part of that project a meta-analysis was performed of the fishers' compliance with the closure (Gribble and Robertson 1998). Therefore, the Poiner *et al.* (1998) data set combined with the Gribble (2000) ecosystem model provided the opportunity to (*1*) evaluate the ecological impact of the cross-shelf closure as an example of an MPA, and (*2*), given the reality of fishers non-compliance, to evaluate the effectiveness of the cross-shelf area that was actually protected; ie the "effective" MPA.

METHODS

Main characteristics of the ECOPATH model

The ecosystem simulations of the northern GBR used ECOPATH EwE software (Christensen *et al.* 2000) using the ECOSYM and ECOSPACE routines for temporal and spatial simulations respectively. More detail on the structure and underlying equations of ECOPATH, and of the base "GBR-prawn" model, is presented in Appendix 1, on the ECOPATH website www.ecopath.org, and in Gribble (2000) respectively. A complete copy of the "GBR-prawn model" is accessible through the ECOPATH website.

Parameter estimates

Estimates of species composition and biomass of the major avian, reptile, fish, mollusc and crustacean assemblages (including the target prawns and discards), as well as diet, consumption and production were calculated from

- two annual cross-shelf prawn-trawl surveys in the 10,000 sq km far-northern GBR study area (Fig. 1). Biomasses of fish and non-fish taxa were based on parallel fish-trawling and benthic dredge samples taken at the time of the prawn surveys (Poiner *et al.* 1998);
- the literature on prawn predation (Brewer *et al.* 1991; Salini *et al.* 1990, 1992, 1998; Haywood *et a1.* 1998; Randall *et al.* 1990; Roman *et al.* 1990);
- FISHBASE (Froese and Pauly 2002) fish database; and
- previously published Ecopath models: (*a*) the trophic interactions in Caribbean coral reefs, Opitz (1993, 1996), and (*b*) for the shrimp fishery in the Southwest Gulf of Mexico (Sherry Manickchand-Heileman *pers.comm.*).

All data not derived from the GBR surveys were taken from tropical prawn (shrimp) grounds with similar general characteristics. The 'GBR-prawn' model deals mainly with the inner lagoon and inter-reef trawl grounds (80–90% of the World Heritage Area, Poiner *et al.* (1998)) rather than attempting a full-scale model of the entire GBR reef ecosystem. The coral reefs proper were included, as was the reef line fishery, but the model represents a simplification and generalisation of the fractal-like complexity of this ecosystem. Estimates of biomass, consumption, production and diet matrices (see Gribble 2000) represent the underlying assumptions of the model, and a different set of assumptions may also produce a balanced model. As with all models, the aim was to capture the major biomass dynamics and flows of the much more complex 'real' system. Heuristic validation of the basic model using historic logbook data has been reported separately in Gribble (2000) and Gribble (in press).

Spatial simulations

The model was made spatially explicit by mapping four broad habitat types, inner lagoon, inshore reefs/islands, reef/shoals and outer lagoon (Fig. 1) onto a virtual landscape and moving the trophic guilds across them. The land and islands were mapped as "no-movement areas" and the trophic guilds distributed around rather than across them (Fig. 2). Movement rates were set at biologically reasonable speeds for typical species within each guild.

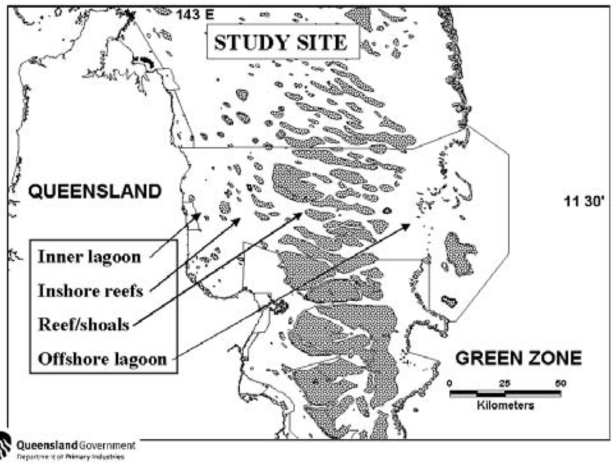


Fig. 1. Queensland, Australia, showing the far-northern Great Barrier Reef study area: Dashed line, border of the Far Northern GBR Cross-shelf Closure Area; Dotted areas, shoals and submerged reefs.

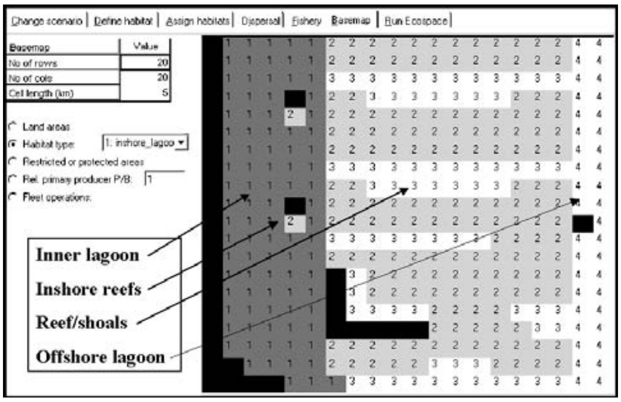
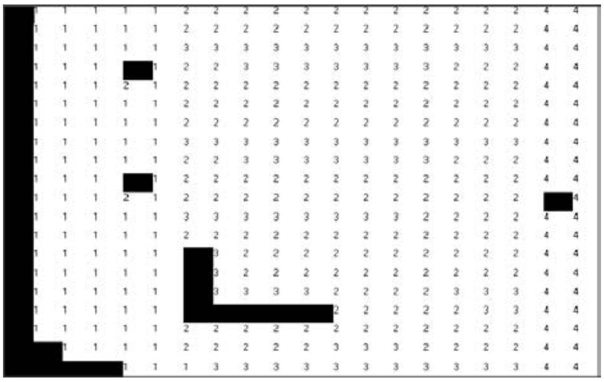


Fig. 2. Simulated far-northern Great Barrier Reef study area taken from the input screen of the ECOPATH EwE, ECOSPACE simulation.

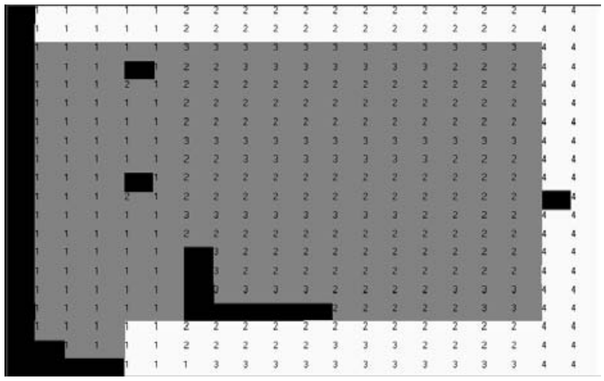
The fishery component of the model was divided into two fleets:

- The reef line fishery for large reef/inter-reef carnivores, both schooling and non-schooling fish, which was combined with the harvest of turtles by indigenous people (FLEET 1); and
- The prawn trawl fishery for penaeid prawns (FLEET 2), which produces the highest proportion of discarded by-catch, mainly small fish. Poiner *et al.* (1998) conservatively estimated a ratio of 6:1 by weight of by-catch to retained catch.

The trawl fleet could fish in both the inshore lagoon and the inter-reef area but the cost of fishing increased by 10% to 40% further offshore into the inter-reef habitat. The line-fishery fleet was restricted to the reef-shoal and inter-reef habitats. Again, it was made slightly more 'costly' to line fish in the offshore sections of these habitats rather than in the more accessible inshore edge of the reef-shoal and inter-reef. The rationale for these increasing costs were the increased fuel required to travel further offshore, increasing loss of fishing gear in the rougher terrain, and an increased risk of boat damage in the poorly charted offshore reef-shoal zone. Further out, the offshore lagoon habitat was not fished in this simulation because of its exposed position, very rough ocean floor (extensive plate coral), and to provide a refugium for turtles and seabirds around nest-site islands and shoals. This scenario broadly matched the known fishing behaviour of trawlers and line fishers in the far northern GBR (Gribble and Robertson 1998; Poiner *et al.* 1998). MPAs were mapped as "no-fishing" overlays and the fishing fleets distributed around rather than across them (Fig. 3).



(a)



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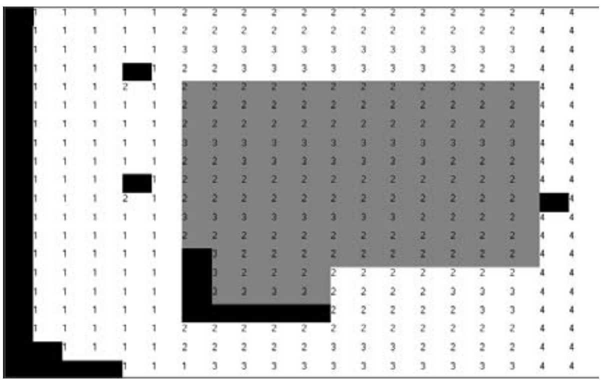

(c)

Fig. 3. Simulated spatial distribution ("Virtual") maps of MPA scenarios applied to the far-northern Great Barrier Reef study area: (*a*) Null simulation with no MPA (but with *de facto* refugia); (*b*) Full "cross-shelf closure" MPA; (*c*) "Effective" MPA based on known patterns of fishing effort

Results from scenario simulations

Note: Computer modelling is an iterative process involving a series of changes to the input parameters of the model to simulate a new scenario. The basic ECOPATH model described was used in each scenario outlined, with the relevant changes to the input parameters detailed. This iterative process produces a combination of "methods" and "results" that is reported in this section.

The Northern GBR Ecosystem model used ECOSYM as a 10-year stanza, with constant fishing by all fleets at present effort levels. The results of imposing a number of spatial maps (Fig. 3) over this basic temporal simulation are provided in Table 1. The spatial maps (ECOSPACE simulations) comprised (*1*) a Null simulation with no MPA, but with natural "*de facto*" refugia, (2) a Full "cross-shelf closure" MPA and (3) an "Effective" MPA based on known patterns of fishing effort.

Changes in the spatial distribution of four trophic guilds (small fish omnivores, sea turtles, large groupers and sea birds) were followed in detail as representative of the dynamics of the general spatial simulations and for the particular interest in these groups as protected species or as accepted indicators of environmental change. Small fish omnivores, for example, were the major component of discarded trawl by-catchand their fate is highly contentious. Similarly, the fate of sea turtles, large groupers, and sea birds is of significant concern to international conservation groups.

Table 1. Simulated changes in Biomass (t/km^2) for each trophic guild in the ECOPATH model of the far northern GBR for (*1*) Null simulation with no MPA (but with *de facto* refugia), (*2*) Full "cross-shelf closure" MPA and (*3*) "Effective" MPA based on known patterns of fishing effort. "Start biomass" is the initial value for each trophic guild for the equilibrium model of the far-northern GBR ecosystem

Trophic Guild	Biomass (Start)	ΔBiomass (1) No MPA	ΔBiomass(2) Full MPA	ΔBiomass(3) "effective" MPA
Cephalopods	0.333	0.95	0.96	0.94
Large groupers	0.032	**1.90**	**2.87**	**1.97**
Scombrids/jacks	2.026	1.03	1.08	1.08
Sea birds	0.014	**0.77**	**0.90**	**0.82**
Large sharks/rays	0.564	0.97	0.90	0.93
Small schooling fish	3.062	0.87	0.86	0.97
Large fish carnivores	1.795	0.97	0.94	0.98
Large schooling fish	0.590	0.88	0.92	0.96
Penaeus longistylus	0.088	1.03	0.89	0.88
Other prawns	0.234	1.18	1.27	1.04
P. esculentus	0.176	0.88	0.56	1.02
Small fish omnivore	2.557	**0.93**	**0.95**	**0.79**
Sea turtles	0.009	**2.53**	**5.12**	**2.52**
Crustaceans	2.822	0.95	1.00	0.97
Metapenaeus endeavouri	0.144	0.80	0.52	0.84
Echinoderms	8.397	0.97	0.94	0.99
Benthic mollusc/worms	10.942	0.96	0.95	0.98
Zooplankton	3.739	0.97	0.97	0.99
Sessile animals	31.300	1.01	1.04	1.00
Fish herbivore	7.435	0.98	0.95	0.95
Decomposer/microfauna	5.996	0.98	0.98	0.98
Phytoplankton	7.652	0.98	0.98	0.97
Benthic autotrophs	174.748	0.99	0.99	1.00
Detritus/discards	53.513	0.83	1.12	0.90
Detritus	40.060	0.99	0.99	0.99
Total		0.96	1.01	0.98

Note: ΔBiomass is the relative change in biomass away from the start biomass, ie 1 = no change, >1 is an increase in biomass, <1 is a decrease in biomass.

Null scenario

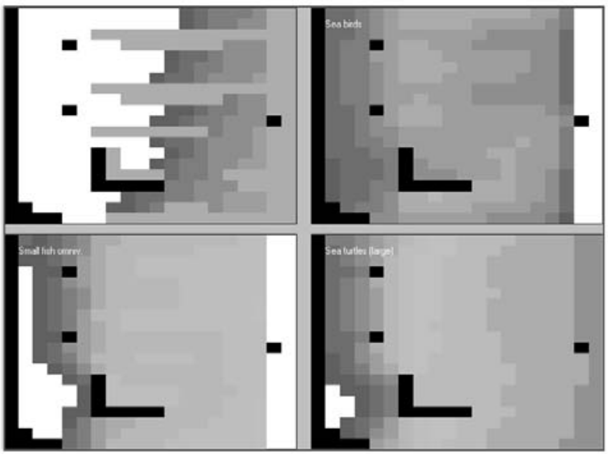

Fig. 4. Spatial dynamics of *small fish omnivores*, *sea turtles*, *large groupers* and *sea bird* trophic guilds under the Null scenario, with no MPA (but with *de facto* refugia).

Under the "Null" set of assumptions, no MPA was applied and the trophic guilds were allowed to distribute across the underlying spatially explicit map of habitat types, and fishing was allowed in all areas.

Fleet dynamics

Trawl fleet. The availability of target prawn species in the inner lagoon, combined with the increasing cost of trawling deeper into the reef-shoal zone, resulted in a concentration of the trawl fleet in the inner lagoon and the inter-reef gutters. This distribution of effort provided areas in the outer reef/shoal and outer lagoon where trawling did not or could not occur, which acted as *de facto* refugia for vulnerable species.

Line fishery fleet. The line fishery was spread across the reef-shoal zone but concentrated along the easily accessible inner edge, grading back into the middle reef-shoal zone. Again this provided areas in the outer reef/shoal and outer lagoon that were only lightly fished and acted as de facto refugia for vulnerable species.

Trophic guild dynamics (Fig. 4)

Large groupers (upper left). These animals were restricted to the main reef-shoals and to the offshore lagoon.

Sea birds (upper right). Reasonably well spread across the study area with an increased density along the inner edge of the reef-shoal zone.

Small fish omnivores (lower left). Again reasonably well spread but with a relatively lower density in the inner lagoon and inter-reef areas associated with the distribution of highest trawling effort.

Sea turtles (lower right). These species were concentrated in the outer reef-shoal zone and outer lagoon.

The addition of *de facto* spatial refugia (but no MPA) to the basic temporal simulation of the GBR ECOPATH model had the overall effect of favouring the vulnerable species and conversely not favouring the scavenger/coloniser species (Table 1). In a balanced temporal simulation, with all factors including fishing effort kept constant, the relative change in biomass (delta biomass) would be 1; i.e. the start and finish biomass for each species would be equal. Therefore the effect of adding a spatial component would show as changes in the delta biomass; greater than 1 would represent an increase in relative biomass and less than 1 a decrease in relative biomass.

From Table 1, both the vulnerable *Large groupers* and *Sea turtles* guilds increased their relative biomass while the biomass of scavenger *Sea birds* decreased. The small drop in *Small fish omnivores* biomass, the major component of discarded trawl by-catch, was somewhat counter-intuitive but was caused by the spatial concentration of trawl effort in the prime habitat for these species.

FULL MPA SCENARIO

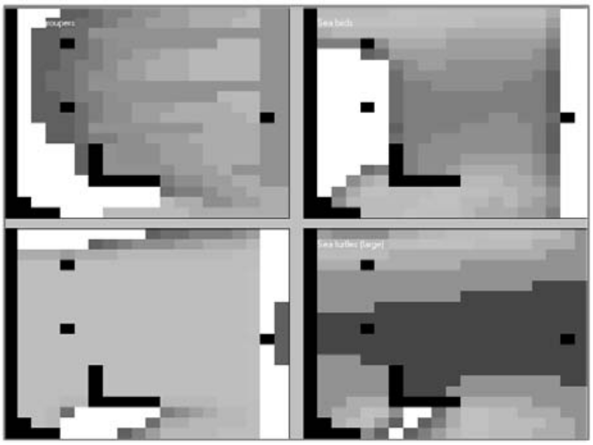

Fig. 5. Spatial dynamics of *small fish omnivores*, *sea turtles*, *large groupers* and *sea bird* trophic guilds under the Full "cross-shelf closure" MPA scenario.

Under the "Full MPA" set of assumptions, the 1985 GBRMPA cross-shelf area closure MPA was applied and the trophic guilds were allowed to distribute across the underlying spatially explicit map of habitat types, but no fishing was allowed within the closed area.

Fleet dynamics

Trawl fleet. Assuming complete compliance with the closure, the trawl effort was redistributed in concentrated bands to the northern and southern borders of the MPA. Along the southern border this is unlikely because the sea bottom is not suitable for otter trawling, unless extensive clearing is carried out (which may have occurred in other areas of the inter-reef area in the past). Trawling was concentrated in the "open" sections of the inner lagoon, grading across the reef-shoal zone to zero in the outer lagoon

Line fishery fleet. Line fishing effort was concentrated in the reef-shoal zone, along the northern and southern borders of the MPA. Again this was a concentrated redistribution of the effort displaced from within the MPA.

Trophic guild dynamics (Fig. 5)

Large groupers (upper left). These animals were no longer restricted to the main reef-shoals and to the offshore lagoon. Density increased and the distribution spread from these zones into the inter-reef.

Sea birds (upper right). Sea birds concentrated along the northern and southern borders of the MPA, associated with the fishing activity and its discarded by-catch.

Small fish omnivores (lower left). Given that these species are the major component of the discarded trawl by-catch, removal of trawling in the MPA increased both their density and the spatial distribution. Conversely, the increased (displaced) trawl effort along the MPA borders caused an apparent depletion of these species on the northern and southern borders of the MPA.

Sea turtles (lower right). These species were apparent winners from the imposition of a full MPA. Both the relative density and spatial distribution of the turtles increased, with these animals spreading into the inter-reef area and inner lagoon.

The result for the sea turtles can be explained in part from the data in Table 1. The turtle biomass incorporated in the model at the start of the simulation was very small; hence, any added turtles would have caused a dramatic change to the relative biomass. This can be seen in the delta biomass measure for sea turtles reported for the "Full MPA" simulation (Table 1). The spatial simulation of a cross-shelf MPA shows the overall effect of favouring the vulnerable species and conversely not favouring the scavenger/coloniser species.

"Effective" MPA, based on known patterns of fishing compliance

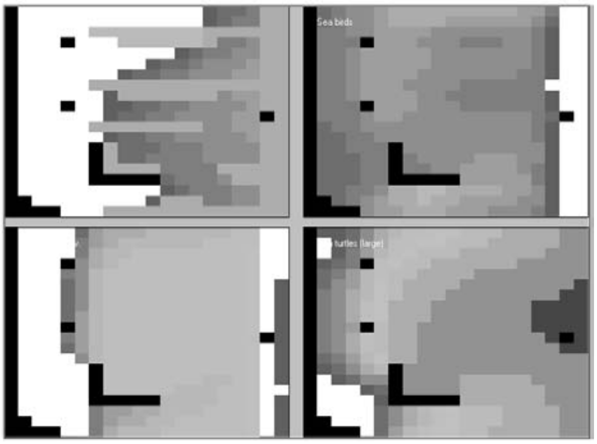

Fig. 6. Spatial dynamics of *small fish omnivores, sea turtles, large groupers* and *sea bird* trophic guilds under the "Effective" MPA scenario, based on known patterns of fishing effort.

The spatial pattern of compliance with the cross-shelf closure was taken from Gribble and Robertson (1998) as:

1. The northern and southern borders of the cross-shelf area closure were subject to "edge effects" as trawlers over-ran hauls that were legally started in the adjacent open zones;
2. the inshore strip of the cross-shelf closure was subject to illegal fishing along the navigation corridor; and
3. the offshore reef-shoal area of the cross-shelf closure is best described as lightly fished and hence was the most protected.

Under the "effective MPA" set of assumptions, the trophic guilds were allowed to distribute across the underlying spatially explicit map of habitat types, but fishing was allowed to follow the above pattern of compliance within the Great Barrier Reef Marine Park far-northern cross-shelf area closure MPA.

Fleet dynamics

Trawl fleet. Trawl effort was concentred along the inner lagoon and northern and southern borders. Because the high-value target species were distributed in the inner lagoon, the model predicts that this zone would take the highest levels of illegal trawling.

Line fishery fleet. Non-compliance in the line fishery was restricted to the northern and southern borders of the MPA. The northern border was predicted to have the highest level of illegal fishing (poaching), possibly because of the more open "less costly" reef-shoal habitat on this border. On the southern border the outer lagoon is closer to the coast, compressing the habitat zones into narrower bands (Fig. 1).

Trophic guild dynamics (Fig. 6)

Large groupers (upper left). The distribution of groupers was intermediate between the "No MPA" and "Full MPA" simulations. Biomass was down on the northern reef shoals but was maintained within the core protected area.

Sea birds (upper right). Sea birds had redistributed to follow the trawl fishing, along the inshore edge of the reef-shoal zone.

Small fish omnivores (lower left). These species were heavily depleted in the inner lagoon, again associated with the concentration in trawl fishing.

Sea turtles (lower right). The relative density and spatial distribution of the turtles increased from the "No MPA" simulation, with these animals spreading into the inter-reef area in the core protected area away from the border "edge effects".

From Table 1, the vulnerable *Large groupers* and *Sea turtles* increased their biomass while the biomass of scavenger *Sea birds* decreased, relative to the "No MPA" simulation. The drop in biomass of *Small fish omnivores* across all scenarios was again somewhat counter-intuitive. The spatial concentration of the displaced trawl effort in the inner lagoon, and the associated high by-catch mortality, is a possible cause for this effect. The altered pattern of trawling may present a gauntlet that *Small fish omnivores* must run in their normal movement.

DISCUSSION

As a refugium, the Great Barrier Reef Marine Park far-northern cross-shelf area closure MPA appears to be selectively beneficial across trophic guilds. Ecosystem modelling suggests that species from high trophic levels, taken mainly by the reef-line fishery, and species from low trophic levels, taken mainly by the prawn trawl fishery, react differently to the reduction of fishing pressure afforded within an MPA. Commercially trawled prawns, *Penaeus esculentus* and *Metapenaeus endeavouri*, which are opportunistic species, do better under the "No MPA" and "effective MPA" scenarios (where the inner lagoon was intensely trawled) than under a full MPA, where no trawling occurred (Table 1). By contrast the s*combrids/jacks* and *large schooling fish,* targeted by the reef-line fishery, did relatively better under the MPAs simulated (Table 1). This was partly because their primary habitat was protected from fishing but also because their life history made them more at risk to population depletion through fishing mortality.

The underlying mechanism determining the effect of a MPA on a trophic guild can be described from Connell's Intermediate Disturbance theory (Connell 1978). A reduction in disturbance (fishing) may actually reduce biodiversity as the ecosystem stabilises at its climax stage. Communities under low disturbance tend to be dominated by fewer, "good competitor" species, rather than by opportunistic colonisers, which flourish under disturbed conditions. On a continuum of disturbance, it would be expected that a dynamic balance exists between colonisers and competitors, and consequently among the various trophic guilds. If an MPA was applied to an area that had previously been heavily fished, this could cause a reverse fishing cascade (see Pauly *et al.* 1993), where increasing numbers of higher-level predators reduce the large biomass of colonising prey species.

In none of the MPA simulations did the relative biomass of the *Small fish omnivores* trophic guild increase, and in the "Effective MPA" scenario it actually decreased (Table 1). MPAs did not decrease the fishing pressure on this trophic guild across the study area. The closure simply caused that fishing pressure to be displaced and concentrated outside the MPA. Because of the wide spatial distribution of this trophic guild it was still vulnerable to this displaced fishing pressure. Spatial concentration of fishing effort appears to have a gauntlet effect on the movement of this guild, hence the modelling would suggest that spatial pattern of the displaced fishing needs to be considered as well as changes in its magnitude.

The ecosystem model evaluation of the Great Barrier Reef Marine Park far-northern cross-shelf area closure MPA suggested the following:

- Spatially explicit habitat data, when applied to population dynamics models, can significantly buffer the predicted volatility in fish biomass by providing *de facto* spatial refugia from fishing pressure (see scenario simulation 1);
- An MPA must be of adequate size to allow for non-compliance "edge effects", particularly if the MPA is sited in remote areas (scenario simulations 2 and 3);
- Fishing will tend to concentrate on borders of the MPA, which may produce "gauntlet" effects on mobile species (scenario simulations 2 and 3); and
- Vulnerable species will do better within an MPA, but scavenger/opportunistic species will do worse (comparison of scenario simulations, Table 1).

With any change to the ecosystem there will be both winners and losers; sometimes, however, these can be counter-intuitive. Managers need to consider both the local and the broadscale consequences of interventions such MPAs, with a view to the risks and the likely outcomes, across the whole of the ecosystem they are attempting to manage.

ACKNOWLEDGMENTS

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APPENDIX 1.

Christensen *et al.* (2000) describes the ECOPATH approach as

“The first Ecopath equation describes how the production term for each ecosystem group (i) can be split in components. This is implemented with the equation,

Production = catches + predation mortality + biomass accumulation + net migration + other mortality; **Eq. 1**

or, more formally,

$$P_i = Y_i + B_i \cdot M2_i + E_i + BA_i + P_i \cdot (1 - EE_i) \qquad \textbf{Eq. 2}$$

where P_i is the total production rate of (i), Y_i is the total fishery catch rate of (i), $M2_i$ is the total predation rate for group (i), B_i the biomass of the group, E_i the net migration rate (emigration – immigration), BA_i is the biomass accumulation rate for (i), while $M0_i = P_i \cdot (1\text{-}EE_i)$ is the ‘other mortality’ rate for (i).

This formulation incorporates most of the production (or mortality where a prey is consumption for a predator) components in common use, perhaps with the exception of gonadal products. Gonadal products however nearly always end up being eaten by other groups, and can be included in either predation or other mortality.

This equation, **Eq. 2** can be re-expressed as

$$B_i \cdot (P/B)_i - \sum_{j=1}^{n} B_j \cdot (Q/B)_j \cdot DC_{ji} - (P/B)_i \cdot B_i \cdot (1 - EE_i) - Y_i - E_i - BA_i = 0$$

Eq. 3

or

$$B_i \cdot (P/B)_i \cdot EE_i - \sum_{j=1}^{n} B_j \cdot (Q/B)_j \cdot DC_{ji} - Y_i - E_i - BA_i = 0$$

Eq. 4

where: P/B_i is the production/biomass ratio, Q/B_i is the consumption / biomass ratio, and $DC_{j,i}$ is the fraction of prey *(i)* in the average diet of predator *(j)*.

Based on Eq. 3, for a system with *n* groups, *n* linear equations can be given, in explicit terms,

$$B_1 \cdot (P/B)_1 \cdot EE_1 - B_1 \cdot (Q/B)_1 \cdot DC_{11} - B_2 \cdot (Q/B)_2 \cdot DC_{21}$$
$$\ldots - B_n \cdot (Q/B)_n \cdot DC_{n1} - Y_1 - E_1 - BA_1 = 0$$
$$B_2 \cdot (P/B)_2 \cdot EE_2 - B_1 \cdot (Q/B)_1 \cdot DC_{12} - B_2 \cdot (Q/B)_2 \cdot DC_{22}$$
$$\ldots - B_n \cdot (Q/B)_n \cdot DC_{n2} - Y_2 - E_2 - BA_2 = 0$$
$$\vdots$$
$$B_n \cdot (P/B)_n \cdot EE_n - B_1 \cdot (Q/B)_1 \cdot DC_{1n} - B_2 \cdot (Q/B)_2 \cdot DC_{2n}$$
$$\ldots - B_n \cdot (Q/B)_n \cdot DC_{nn} - Y_n - E_n - BA_n = 0$$

Eq. 5

This system of simultaneous linear equations can be re-expressed

$$a_{11}X_1 + a_{12}X_2 + \ldots a_{1m}X_m = Q_1$$
$$a_{21}X_1 + a_{22}X_2 + \ldots a_{2m}X_m = Q_2$$
$$\vdots$$
$$a_{n11}X_1 + a_{n2}X_2 + \ldots a_{nm}X_m = Q_n$$

Eq. 6

with *n* being equal to the number of equations, and m to the number of unknowns.

This can be written in matrix notation as

$$[A]_{nm} \cdot [X]_m = [Q]_m$$ **Eq. 7**

Given the inverse A^{-1} of the matrix A, this provides

$$[X]_m = [A^{-1}]_{n,m} \cdot [Q]_m$$ **Eq. 8**

If the determinant of a matrix is zero, or if the matrix is not square, it has no ordinary inverse. However, a generalised inverse can be found in most cases (Mackay 1981). In the Ecopath model, the approach of Mackay (1981) is used to estimate the generalised inverse. If the set of equations is over-determined (more equations than unknowns), and the equations are not consistent with each other, the generalised inverse method provides least squares estimates, which minimises the discrepancies. If, on the other hand, the system is underdetermined (more unknowns than equations), an answer that is consistent with the data will still be output. However, it will not be a *unique* answer.

Of the terms inEq. 3, the production rate, P_i, is calculated as the product of B_i, the biomass of (i) and P_i/B_i, the production/biomass ratio for group (i). The P_i/B_i rate under most conditions corresponds to the total mortality rate, Z, see Allen (1971), commonly estimated as part of fishery stock assessments. The 'other mortality' is a catch-all term including all mortality not elsewhere included, e.g., mortality due to diseases or old age, and is internally computed from,

$$M0_i = P_i \cdot (1 - EE_i)$$ **Eq. 9**

where EE_i is called the 'ecotrophic efficiency' of (i), and can be described as the proportion of the production that is utilized in the system. The production term describing predation mortality, M2, serves to link predators and prey as,

$$M2_i = \sum_{j=1}^{n} Q_j \cdot DC_{ji}$$ **Eq. 10**

where the summation is over all (n) predator groups (j) feeding on group (i), Q_j is the total consumption rate for group (j), and DC_{ji} is the fraction of predator (j)'s diet contributed by prey (i). Q_j is calculated as the product of B_j, the biomass of group (j) and Q_j/B_j, the consumption/biomass ratio for group (j)."

ROLE OF FISHING CLOSURES AND HABITAT IN CONSERVING REGIONAL ESTUARINE BIODIVERSITY: A CASE STUDY IN NORTHERN QUEENSLAND, AUSTRALIA

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Abstract

In multi-species fisheries along the north-eastern Australian coast, gillnets (150–215 mm mesh size) may be set within estuaries to catch and market species in the Families Centropomidae, Polynemidae, Mugilidae and Carangidae. Certain riverine estuaries have been closed to commercial net fishing for at least 7 years within this region.. To quantify the effect of fishing closures, our research teams deployed gillnets bimonthly over a 2 year period at upstream and downstream sites within 3 pairs of systems (one closed and one neighbouring estuary open to commercial net fishing per pair) under a complete factorial sampling design.

In larger mesh research nets, catch biomass of target species was systematically greater in closed than open systems, averaging 16 versus 4 kg/set for 152 mm nets, and 21 versus 11 kg/set overall for 102 mm nets. Canonical correlation analysis indicated that although fishing was the most influential factor, salinity, temperature and mangrove area were also ecologically significant determinants of spatial assemblage patterns for species caught in these nets. The benefits of estuarine closures for conservation of multispecies fisheries and biodiversity would be more fully realised by establishing regional networks of strategically selected systems spanning a range of broadscale habitat conditions.

Keywords: estuaries, gillnets, aquatic protected areas, canonical correlation analysis, biodiversity, multispecies fishery

INTRODUCTION

Fishery objectives related to aquatic reserves are generally as follows: (*1*) to conserve populations of target species within refugia as insurance against overfishing, and (*2*) to serve as sources of replenishment through spillover and recruitment (Russ 2002). Aquatic reserves also serve biodiversity objectives by protecting representative habitats within a region (National Research Council 2001; GBRMPA 2003). In regions supporting multi-species fisheries, the potential biodiversity and fisheries benefits of aquatic reserves are inextricably interconnected (Lindeman *et al.* 2000). Ideally, both sets of objectives can be addressed when monitoring the effectiveness of existing aquatic reserves, because diverse fishery resources require a diverse array of habitats. Establishing the influence of key habitat variables on fishery resources in multiple reserves may assist resource managers in developing criteria for future reserve designations.

Effectiveness of aquatic reserves for conservation of fishery species has been studied around the world, primarily focussing on reef habitats. Despite this, many questions about effects of reserve designation on fish populations remain unresolved owing to weaknesses inherent in the design of broad-scale comparative investigations. Ecological impacts of reserve designation would ideally be evaluated by an adequately replicated before-after-control-impact (BACI) design (Russ 2002). But in most case studies, full implementation of this approach has been hampered by such challenges as how to

1. monitor and quantify illegal fishing in the reserve,
2. obtain data from the period before reserve designation,
3. allow adequate time for designation to have an effect,
4. satisfy the need for true replication within the reserve itself,
5. replicate between reserves, and
6. account for distance and habitat variability between open and closed sites.

Some of these limitations also apply to the present study. Firstly, under the Queensland *Fisheries Act 1994*, our 'closed' systems remained open to recreational line fishing and we did not attempt to quantify the level of recreational or illegal commercial fishing in our study. Secondly, sites had been closed primarily to reduce conflict between recreational and commercial fishers, and no before-closure monitoring had taken place. Thirdly, the duration of the designation (7–10 years prior to our surveys) may or may not have been adequate to register the full impact of closure.

However, measures to overcome challenges 4–6 (above) were implemented in our study design. Sampling was replicated within systems at upstream and downstream locations separated by at least 1 km. To replicate between reserves, we sampled pairs of sites among three relatively homogeneous sub-regions spanning a landscape gradient from wet-tropical rainforests in the north to drier eucalypt-dominated floodplains in the south.

We also attempted to control for variability in habitat features of importance to fish between open and closed sites within pairs by selecting sites that were similar in major features (e.g. catchment of origin, outfall water body, rainfall regime, land use). However, this final challenge was the most difficult to overcome because, unlike reef systems, only limited quantitative information is available about the underlying relationships between fish and habitat within tropical estuarine systems (Robertson and Blaber 1992). One reason for this knowledge gap is that few studies have systematically investigated a wide ecological range of fish species in several discrete tropical estuaries simultaneously over several seasons. On the basis of limited comparisons of community composition, the variability in fish-habitat features among estuaries even in close proximity to each other can be substantial (Robertson and Duke 1990; Sheaves 1998).

Estuaries are among the most productive and complex systems in the natural world, and even within individual systems clarification of the influences of habitat features on fauna has been problematic. A general approach for conceptualising the influence of complex habitat variables on species assemblages has been developed (Browder and Moore 1981) but seldom tested against empirical evidence. The basis for this approach is that aquatic forces (e.g. river flow, tides) position an area of favourable dynamic habitat conditions relative to important stationary habitat factors such as channel shape, shoreline features and bottom type. The size and characteristics of the area of overlap of these factors, integrated over time, as well as food concentration, may determine habitat suitability for particular species. Quantifying the broad-scale characteristics of estuarine habitats available to fish requires identification of the nature of the interplay between these stationary and dynamic variables as well as the temporal variation in fish biomass. The present study employed multivariate techniques to investigate how fishing interacts with these habitat factors in determining composition of fish assemblages for six estuaries.

Objectives were (*1*) to quantify the effects of fishing closures on relative biomass of fish assemblages; (*2*) to explore relationships between fish assemblages and broad-scale habitat features; and (*3*) to identify implications of these results for designation of aquatic reserves.

METHODS

Study Area

The study area extended 400 km along the north-eastern Australian coast between Cairns and Bowen in Queensland (Fig. 1). Average annual rainfall is >4000 mm in the north but <1000 mm in the south. In the north, coastal rivers flow through mountainous rainforest catchments; southern rivers flow through broad, level floodplains dominated by eucalypts. Estuarine shorelines are dominated by mangroves, ranging from a narrow fringing band to broad-basin forests. Near their oceanic outfalls these river systems become estuaries that vary in shape, size and dynamics. Queensland's *Fisheries Act 1994* permits recreational line-fishing in riverine estuaries throughout the area. Licensed commercial fishers can set gill-nets in riverine estuaries if stretched-mesh sizes are between 150 and 215 mm. Nine estuaries in the region had been closed to all forms of commercial fishing for at least 7 years before our study, primarily to reduce user conflict, and we focussed on three of these closed systems. For each estuary in which commercial fishing had been banned ("closed"), a nearby estuary open to commercial net fishing ("open") was selected for comparison. Sites in the 3 pairs were sampled upstream (2–7 km from the mouth) and downstream (within 1 km of the mouth). Bimonthly sampling of the 6 estuaries was conducted over the 7-day period of neap tides (0.5 to 1.8 m range). At each of the 12 sampling sites, an array of replicate monofilament gill-nets were deployed; these consisted of two nets each of the following mesh sizes: 152 mm, 102 mm, 51 mm, and multi-panel (19, 25 and 32 mm). Further details about the study sites and sampling procedures are available in Halliday *et al.* (2001) and Ley *et al.* (2002).

Specimens weighed in the laboratory were used to generate a series of equations for each species fitted to the power curve: $W = q L^b$, where W is Weight, L is length, and q and b are constants (King 1998). Biomass was calculated from these

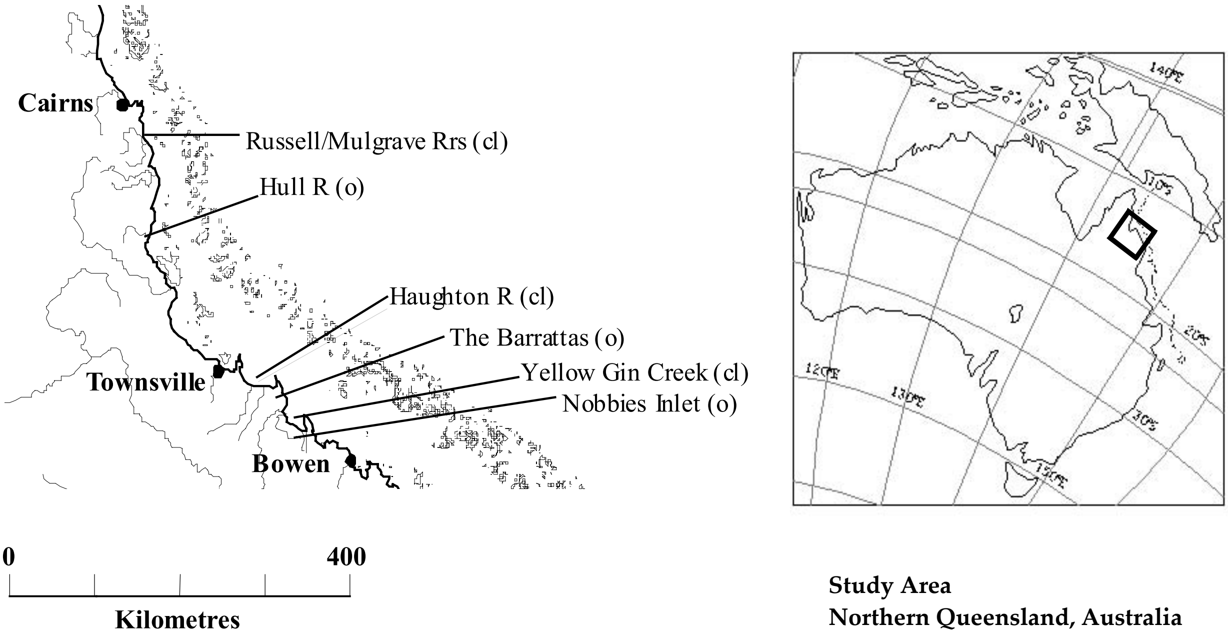

Fig. 1. Study sites in northern Queensland, Australia. Letters indicate the fishing status of each system with o = open to commercial fishing, and cl = closed.

equations, supplemented with data from previous collections by JAL and from FishBase (2002). Throughout the net-soak period, aquatic conditions were measured at 5 min intervals on one or two Hydrolab Datasonds. Salinity, temperature, turbidity, dissolved oxygen, water level and pH were recorded near the net-deployment sites.

Statistical analysis

A complete factorial structure was used in the sampling program, with 3 geographical regions (north = N, middle = M, south = S), 2 fishing policies (open = Op and closed = Cl), 2 positions (upstream = U and downstream = D), 2 replicate nets, and 13 points in time (2 years, bimonthly). Henceforth, sites will be referred to by the initials indicated, e.g. **NOpU** refers to the site in the northern region, open to fishing, upstream location. Analyses were conducted separately for each net type. Thus, each sample represented one night's set of an individual net, making a total of 312 samples per net type.

After examination of residuals, biomass data (grams per set) were square-root (x + 0.5) transformed prior to analyses. Repeated-measures split-plot analysis of variance (ANOVA) was conducted with the covariate soak time (Payne *et al.* 1993). The analysis was treated as a repeated-measures design since the Greenhouse–Geisser epsilon averaged 0.35 for the different mesh sizes, indicating a reasonable degree of autocorrelation (Greenhouse and Geiser 1959). Split-plot analysis of complex factorial designs is applicable when different factors are applied to sampling units at different spatial scales (i.e. in this case: position, system, region) (Quinn and Keough 2002). Because the catch within nets was sometimes very large, the teams were prevented from achieving the 6 h limit for every net set. Thus, the covariate soak time was incorporated into the model to control for variation in set duration. Multiple comparison tests (LSD method) *post hoc* were conducted for all F-tests that were significant at the 5% level.

Multidimensional scaling (MDS) was used to ordinate and view the spatial relationships identified in a similarity matrix (StatSoft 1995). For each net type, matrices were developed to represent biomass of all species summarised by system and month of the year (n = 36), e.g. south-closed-May. Aggregation of the data set at this level of resolution allowed adequate visualisation of spatial and temporal patterns, while reducing the points plotted in the MDS diagram to a reasonable number for interpretation. To examine associations between fish biomass and habitat characteristics, data were examined by canonical correlation analysis (CCA). CCA generates linear combinations of variables (canonical roots) that maximise correlations between two sets of variables while it minimises correlations within sets (Tabachnick and Fidell 2001). The method quantified associations between fish biomass by leading species (fish data set) and a subset of uncorrelated habitat conditions including fishing (habitat data set). Canonical R measures the overall association between the two data sets. Variance extracted measures the percentage variance explained by each root within each individual data set. The redundancy coefficient measures the amount of overall variation in one data set (fish biomass) as predicted by the other (habitat). Chi-square (Bartlett's) tests measure the significance of each canonical root. To assist in interpretation, each of the original variables was correlated to each root; correlations over 0.40 were considered ecologically meaningful (Stein *et al.* 1992).

RESULTS

Habitat variables

Broad-scale habitat features of northern sites differed markedly from mid and southern systems (Table 1). For example, lowest average salinity (12.9 and 15.5) occurred at the two northern sites and highest average salinity (32.8) at the southernmost site. The steep rise in elevation very near the coastline tended to reduce the inland extent of the navigable portion of the rivers in the northern region. However, average index of mangrove area was greatest in the middle region.

Fish biomass

ANOVA results. For mean biomass in finer-mesh nets (multipanel, 51 mm), no systematic differences were discerned between open and closed systems (Table 2, Figs 2a, 2b). In contrast, mean biomass sampled in 102 mm nets was significantly lower for open than closed sites (10.8 kg/set versus 20.9 kg/set). Biomass at each closed site was significantly greater than biomass at its spatially equivalent open counterpart for all but one pair. However, peak biomass levels occurred at 2 of the 6 closed sites, SClU and MClD (Fig. 2c). Similarly, biomass in 152 mm nets averaged 4.2 kg/set at open versus 16.2 kg/set at closed sites ($p<0.0001$). Significantly greater mean biomass was netted at each closed site than at its open counterpart, but peak biomass occurred at one particular site, NClD (Fig. 2d).

Thus, although closed sites had significantly greater biomass than open sites for larger fish (as caught in larger-mesh nets), no differences were discerned for smaller fish. In addition, some of the closed sites had far greater mean biomass than all others.

As found for all species combined, biomass levels of *Lates calcarifer* sampled with 102 and 152 mm nets were significantly and consistently greater at all closed sites, but extreme peaks occurred at MClU and NClD (Table 2, Figs 3a, 3c). In contrast, although mean biomass of *Eleutheronema tetradactylum* in 102 mm nets was greater at closed sites, this trend proved to be inconsistent; at one site (SClU) extreme biomass levels were netted (Fig. 3b). Mean biomass levels of *Scomberoides commersonianus* netted in the 152 mm nets were significantly greater at closed sites for four of the six paired comparisons (Fig. 3d). Thus, fishing apparently led to reduced biomass of *L. calcarifer* and possibly *S. commersonianus* in the open estuaries, but for *E. tetradactylum* no effects of fishing were detected and distributional patterns were greatly skewed towards one particular sampling site.

Trends in spatial distribution by taxa. Research teams netted 24,908 fish, weighing 10.3 tonnes, from 141 species, with only 17 species common to all 12 sampling sites. Of 53 families represented, 8 represented 90% of the biomass. Centropomidae was greatest (37%), followed by Ariidae (17%), Polynemidae (12%), Mugilidae (10%), Carangidae (6%), Haemulidae (4%), Megalopidae (2%) and Carcharhinidae (2%). However, this ranking of the families was not consistent among the estuaries (Fig. 4). For example, approximately 50% of the total biomass netted in the Russell and Haughton systems consisted of barramundi (Centropomidae), but only 20% in Yellow Gin, Nobbies and Hull systems. In fact, threadfin (Polynemidae) comprised the greatest biomass in Yellow Gin Creek and sea catfish (Ariidae) in the Hull River.

MDS diagrams based on species biomass indicated the occurrence of characteristic fish assemblages in each system (Fig. 5). Unexpectedly, the group containing the northern samples overlapped with samples from the southernmost system, Nobbies Inlet. This spatial pattern was observed for the multi-panel, 51 mm and 102 mm nets, but was split for the largest-mesh net (152mm) in which the open sites separated distinctly from closed sites. Thus, effects of fishing on assemblage patterns were observed only for biomass caught in largest-mesh net (152 mm); these were the only research nets equivalent to nets used for commercial fishing directly in the open estuaries (150–215 mm).

Table 1. Mean values of the habitat variables measured for each estuary. Letters indicate groupings determined by one-way ANOVA with LSD multiple comparison tests.

System	Region (fishing)	*Temperature* (°C) *	Salinity ***	pH ***	Turbidity (NTU) NS	Channel length (km)	Elevation (m)	Mangrove (km)	Monthly Rainfall (mm)
Nobbies	South (open)	26.7 b	32.8 a	7.7 a	48	12	50	4.0	120.8
Yellow Gin	South (closed)	26.3 b	25.7 b	7.6 a	79	15	50	3.9	123.7
Barrattas	Mid (open)	27.3 a	22.7 b	7.6 a	68	10	50	6.0	150.6
Haughton	Mid (closed)	27.1 a	23.3 b	7.7 a	68	15	50	9.0	155.6
Hull	North (open)	26.4 b	15.5 c	7.4 b	52	9	100	3.5	542.0
Russell	North (closed)	25.7 c	12.9 c	7.2 c	89	7	250	3.0	511.7
Overall		26.6	22.2	7.5	67	11.3	91.7	4.9	267.4

* $p< 0.05$ ** $p<0.01$ *** $p<0.001$. NS = not significant

Table 2. Results of ANOVA, testing for differences in mean biomass (kg/set) for total catch and the two leading species for each net type.

Net Type	Parameters	Mean Biomass (kg/set)			Interactions of Fishing with:	
		Open	Closed		Position and / or Region	Trip & / or Position, Region
152 mm	Total catch	4.2	16.2	***	***	NS
	Lates calcarifer	2.5	11.2	***	***	NS
	Scomberoides commersonianus	0.3	1.5	***	***	***
102 mm	Total catch	10.8	20.9	***	*	NS
	Lates calcarifer	2.9	7.7	***	***	***
	Eleutheronema tetradactylum	0.2	1.4	**	***	***
51 mm	Total catch	1.9	2.1	NS	NS	NS
	Liza subviridis	0.25	0.31	NS	***	*
	Valamugil cunnesius	0.17	0.31	NS	*	NS
Multipanel	Total catch	0.8	0.7	NS	NS	NS
	Herklotsichthys castelnaui	0.18	0.30	NS	***	*
	Thryssa hamiltonii	0.07	0.06	NS	*	NS

* $p< 0.05$ ** $p<0.01$ *** $p<0.001$ NS = not significant

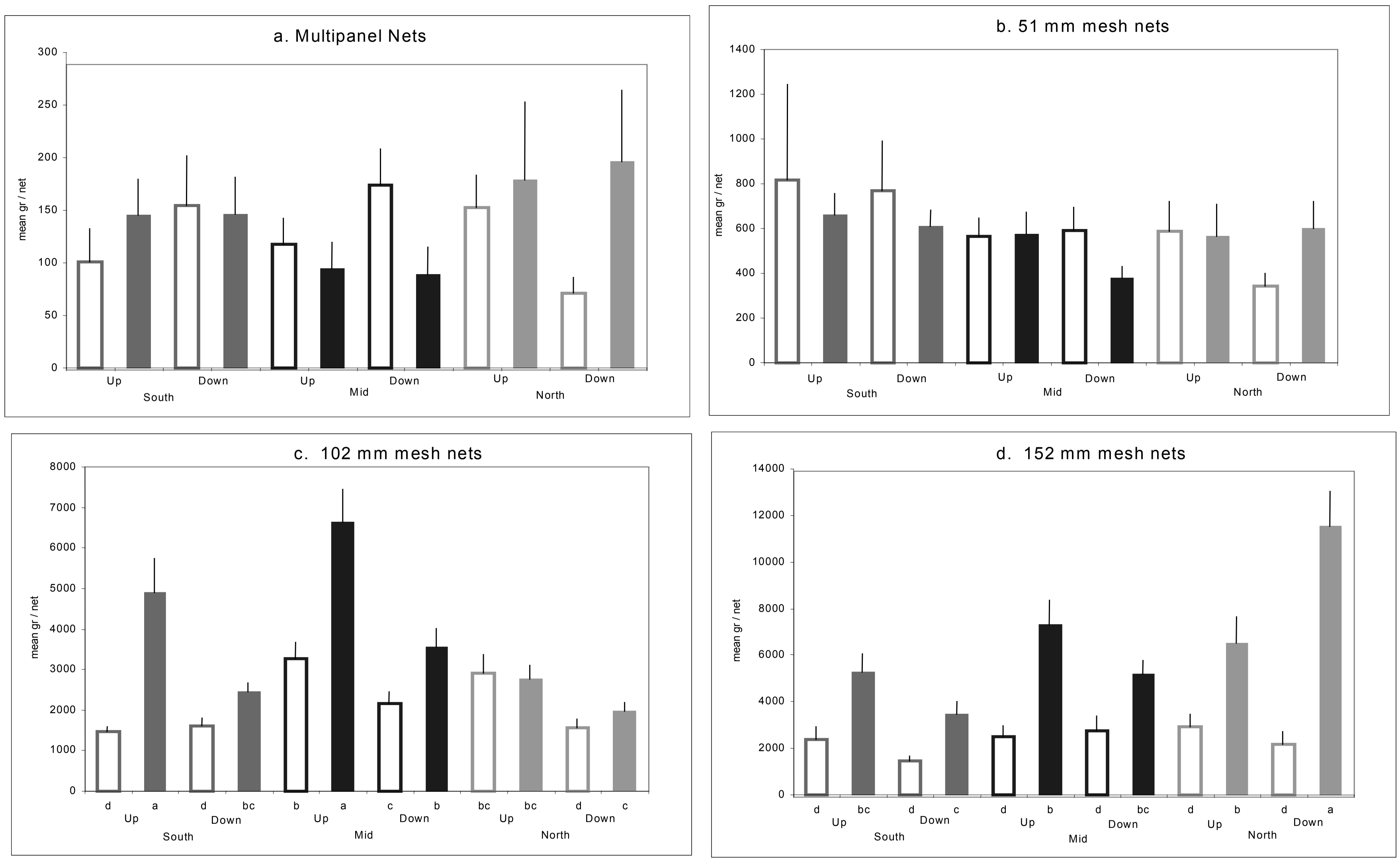

Fig. 2. Mean biomass (kg/set) for all species combined, for each net type. Error bars illustrate 95% confidence intervals. Hollow bars are used for sites open to commercial net fishing and solid bars for closed sites. If ANOVA (Table 2) resulted in a significant difference among sites ($p<0.05$), then letters appear at the base of each bar along the *x*-axis to indicate LSD groupings.

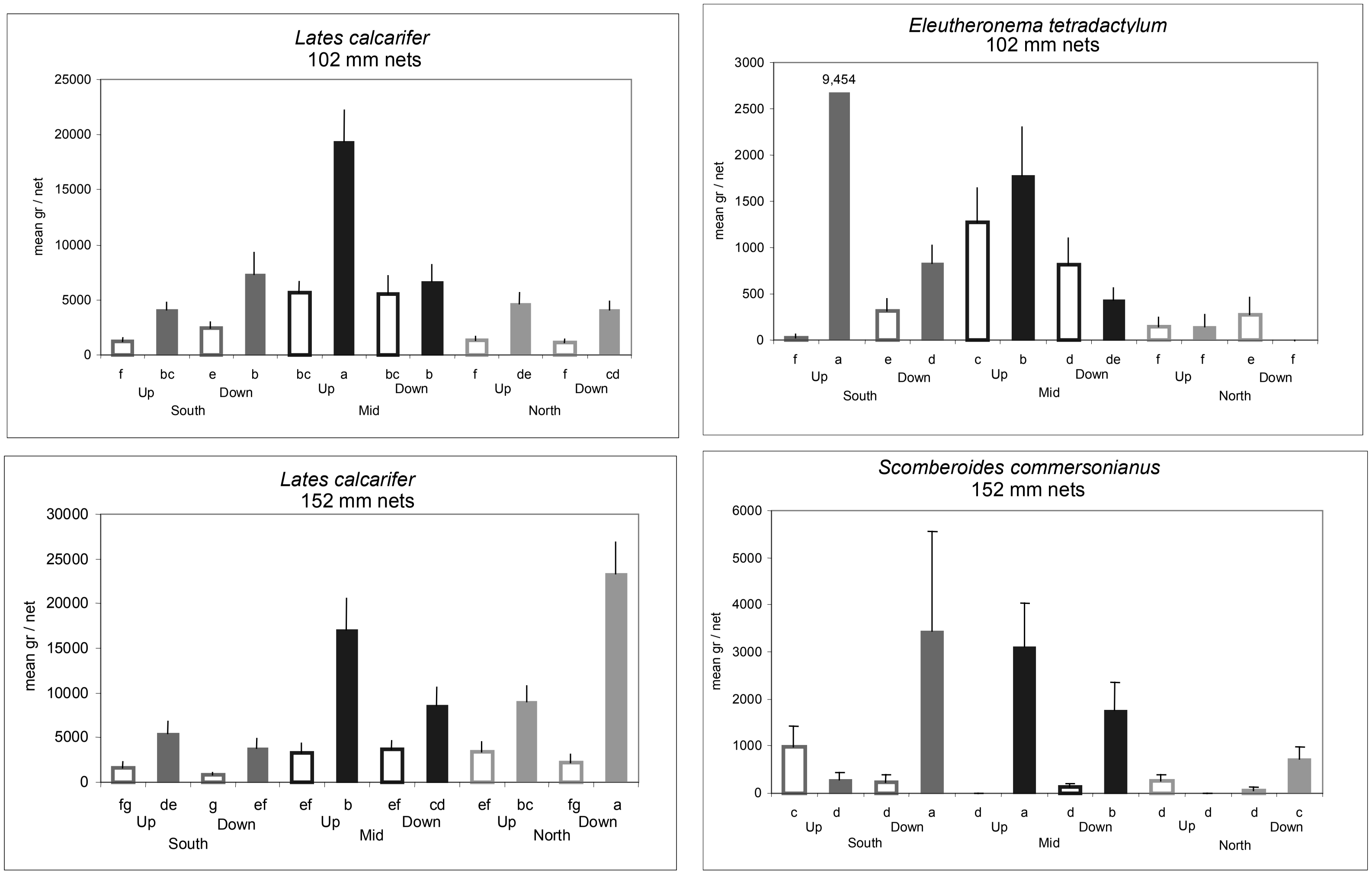

Fig. 3. Mean biomass (kg/set) of the two leading species netted in the larger mesh research nets. Error bars illustrate 95% confidence intervals. Hollow bars are used for sites open to commercial net fishing and solid bars for closed sites. If ANOVA (Table 2) resulted in a significant difference among sites (p<0.05), letters appear at the base of each bar along the x-axis to indicate LSD groupings.

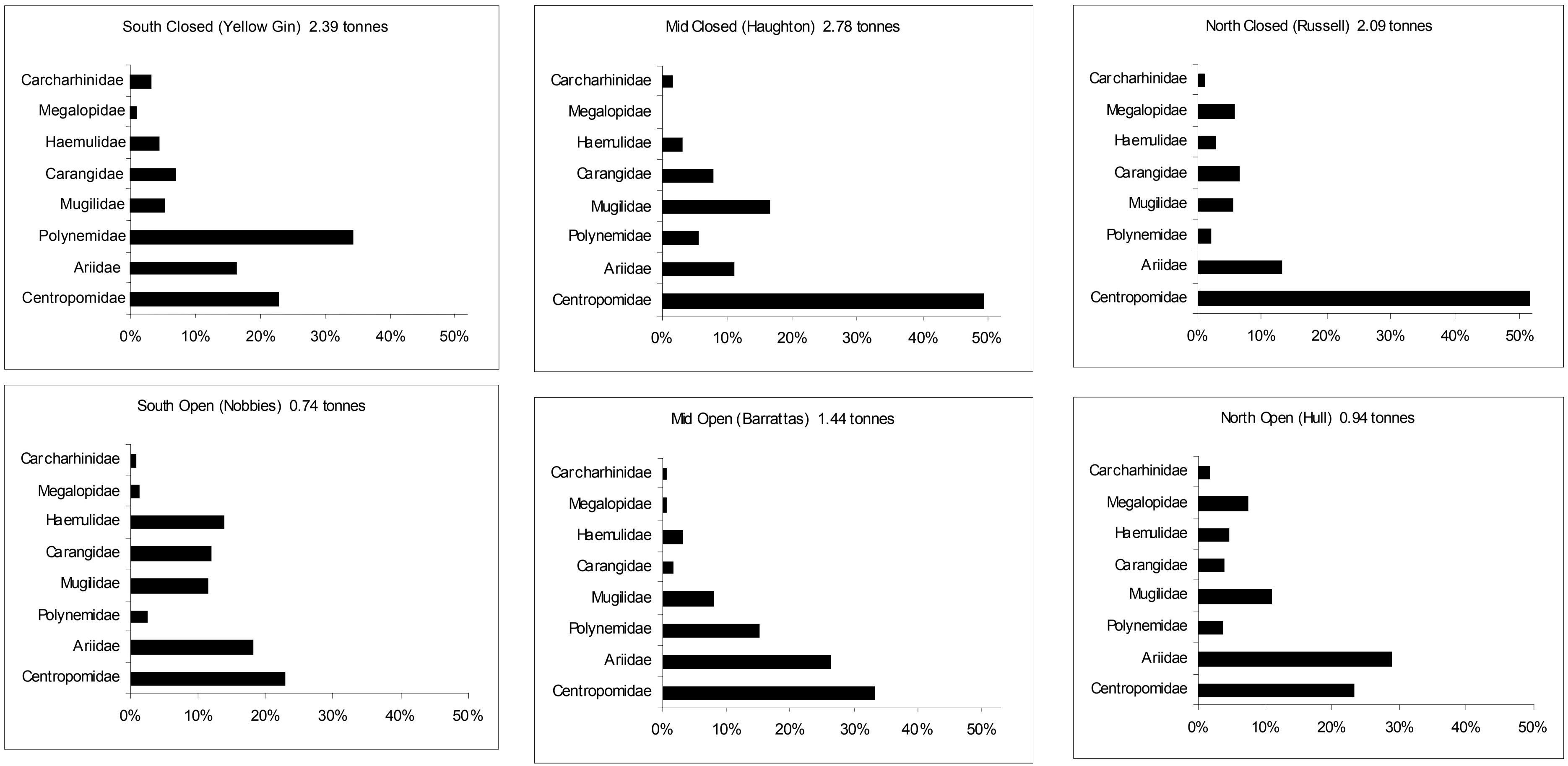

Fig. 4. Comparison of the relative biomass caught in each river by Family, including the families that comprised the top 90% of overall biomass captured in all systems combined

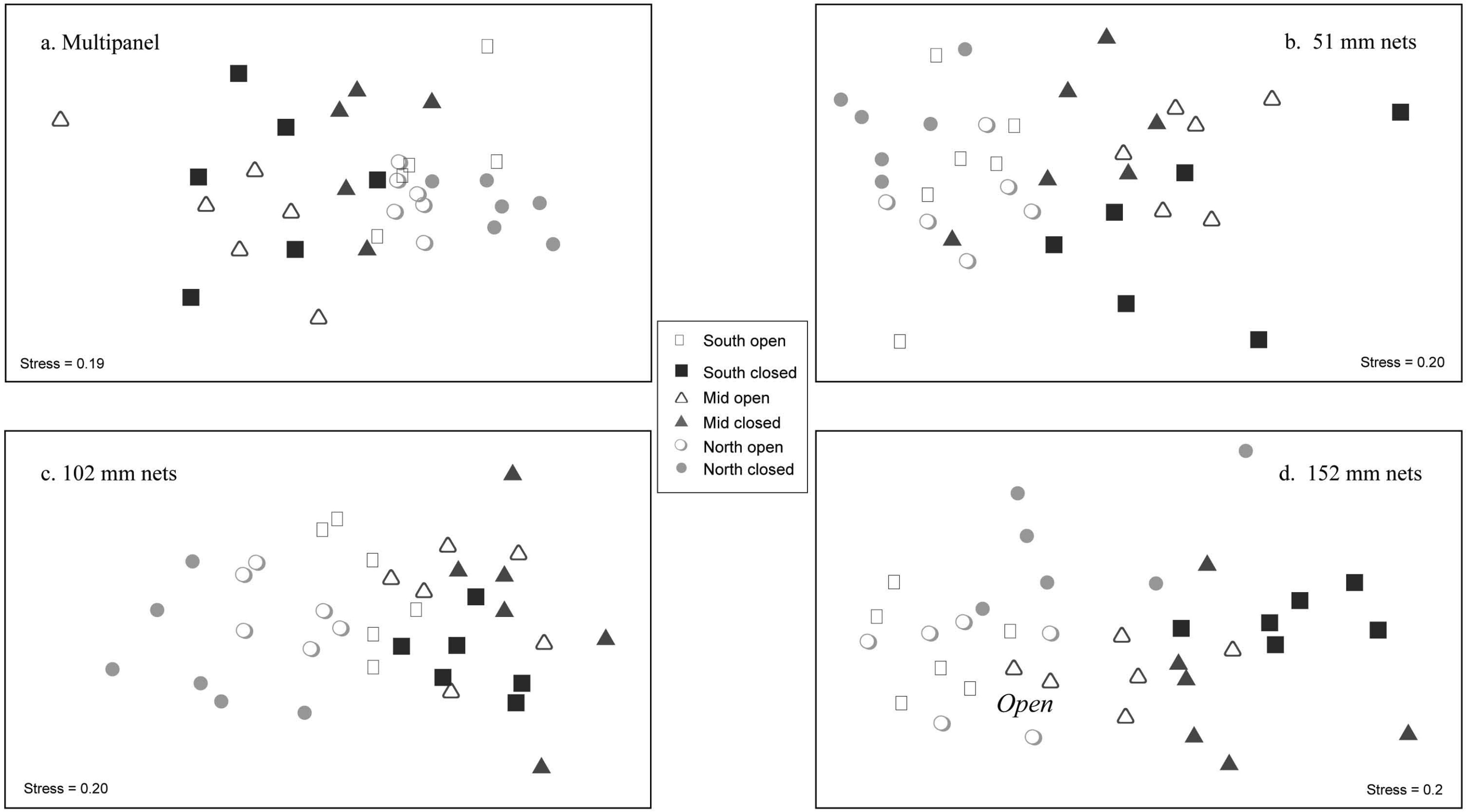

Fig. 5. Multidimensional scaling diagrams illustrating the relative similarity of species biomass among the six estuaries averaged by month ($n = 36$).

Table 3. Canonical correlation analysis for two finer-mesh nets. Analysis tested for linear relationships between the biomass of the leading species of fish (kg/set) and habitat variables for all sampling sites (n = 312).

a. Multipanel nets	Total	CC1	CC2	CC3
Canonical correlation		0.601	0.391	0.351
Chi–square		245.9	114.0	65.3
p		**<0.0001**	**<0.0001**	**<0.0001**
Fish		Correlation with canonical roots		
Ambassis vachelli		–0.11	0.03	**0.41**
Eleutheronema tetradactylum		0.20	–0.02	–0.08
Escualosa thoracata		0.01	**0.50**	0.30
Herklotsichthys castelnaui		**–0.75**	–0.24	0.20
Leiognathus equulus		–0.21	0.52	–0.20
Liza subviridis		**0.54**	–0.04	0.20
Nematalosa come		0.01	**–0.61**	0.32
Strongylura strongylura		0.24	0.27	**0.78**
Thryssa hamiltonii		0.31	0.14	0.18
Variance extracted	36%	12%	12%	13%
Habitat				
Fishing (open=1, closed=0)		0.03	–0.04	0.21
Position (up=2, down=1)		0.03	0.25	**–0.62**
Water temperature		**0.58**	–0.22	**–0.59**
Salinity		0.14	–0.35	0.38
Channel length		**0.79**	–0.13	0.28
Mangrove area index		**0.68**	**0.61**	0.14
Variance extracted	52%	24%	10%	17%
Redundancy	13%	9%	2%	2%
b. CCA 51 mm nets	Total	CC1	CC2	CC3
Canonical correlation		0.50	0.44	0.32
Chi–square		204.57	121.48	56.46
p		**<0.0001**	**<0.0001**	**<0.0011**
Fish		Correlation with canonical roots		
Arius spp.		–0.36	**–0.50**	0.06
Eleutheronema tetradactylum		–0.23	0.04	0.11
Lates calcarifer		–0.27	0.20	–0.02
Liza subviridis		**–0.65**	–0.13	**0.62**
Nematalosa come		–0.09	0.38	0.29
Thryssa hamiltonii		0.11	0.31	**0.45**
Valamugil buchanani		0.07	–0.37	**–0.50**
Valamugil cunnesius		**0.50**	**–0.56**	**0.56**
Valamugil seheli		–0.05	–0.06	0.12
Variance extracted	36%	11%	11%	14%
Habitat				
Fishing (open = 1, closed=0)		–0.05	0.13	–0.39
Position (up = 2, down = 1)		–0.18	0.03	0.10
Water temperature		–0.27	–0.14	**–0.83**
Salinity		–0.06	–0.26	**0.55**
Channel length		**–0.82**	–0.38	0.32
Mangrove area index		**–0.74**	**0.50**	0.17
Variance extracted	52%	22%	8%	21%
Redundancy	9%	5%	2%	2%

Note: Bold type indicates ecologically significant correlations

Table 4. Canonical correlation analysis for two larger-mesh nets. Analysis tested for linear relationships between biomass of the leading species of fish (kg/set) and habitat variables for all sampling sites (n = 312).

a. 102 mm nets	Total	CC1	CC2	CC3
Canonical correlation		0.405	0.366	0.289
Chi–square		133.9	81.3	39.0
p		**<0.0001**	**<0.0007**	0.1853
Fish			Correlation with canonical roots	
Arius spp.		**–0.69**	–0.15	
Eleutheronema tetradactylum		0.05	**–0.84**	
Lates calcarifer		–0.09	0.08	
Leiognathus equulus		–0.36	0.31	
Liza vaigiensis		**0.41**	0.07	
Nibea soldado		–0.01	–0.03	
Pomadasys argenteus		–0.17	–0.35	
P. kaakan		0.13	–0.28	
Scomberoides commersonianus		–0.10	–0.29	
Polydactylus macrochir		–0.05	**–0.40**	
Variance extracted	31%	9%	13%	
Habitat				
Fishing (open=1, closed=0)		0.21	0.02	
Position (up=2, down=1)		**–0.82**	**–0.43**	
Water temperature		–0.35	**0.47**	
Salinity		0.27	**–0.67**	
Channel length		0.12	–0.37	
Mangrove area index		0.26	**–0.47**	
Variance extracted	55%	17%	20%	
Redundancy	8%	3%	3%	
b. 152 mm nets	Total	CC1	CC2	CC3
Canonical correlation		0.556	0.543	0.429
Chi–square		324.8	215.9	113.0
p		**<0.0001**	**<0.0001**	**<0.0001**
Fish			Correlation with canonical roots	
Arius spp.		0.27	0.02	**0.54**
Carcharhinus leucas		0.38	**0.43**	**0.58**
Eleutheronema tetradactylum		0.23	**0.62**	–0.27
Lates calcarifer		**0.81**	–0.22	0.16
Leiognathus equulus		0.17	–0.35	0.14
Liza vaigiensis		0.35	0.18	–0.26
Nibea soldado		–0.10	0.21	0.35
Pomadasys kaakan		–0.33	**0.41**	0.27
Scomberoides commersonianus		0.32	**0.45**	–0.19
Caranx ignobilis		0.13	0.14	0.14
Variance extracted	36%	13%	12%	11%
Habitat				
Fishing (open=1, closed=0)		**–0.83**	–0.27	–0.30
Position (up=2, down=1)		0.23	0.20	0.22
Water temperature		–0.07	–0.22	**0.45**
Salinity		–0.29	**0.58**	–0.11
Channel length		0.04	**0.89**	–0.04
Mangrove area index		**0.41**	0.37	**–0.57**
Variance extracted	52%	17%	24%	11%
Redundancy	14%	5%	7%	2%

Note: Bold type indicates ecologically significant correlations

Biomass–Habitat relationships

The most influential variable in the canonical correlation analysis (CCA) was mangrove area, which was correlated at an ecologically significant level with 8 out of 11 canonical roots (Tables 3 and 4). Temperature and salinity were also ecologically significant factors (6 of 11 cases). Fishing was well correlated only with canonical roots that were associated with largest-mesh nets. In most cases, each canonical root described the correlation between individual species and a set of habitat variables, indicating little tendency for species to group together based on shared preferences for particular sets of habitat variables. In other words, most of the species displayed highly individualised habitat correlations, as described below.

Multipanel nets. Three significant canonical roots corresponded with combinations of linear correlations between fish and habitat data sets (Table 3a; $p < 0.0001$). Habitat roots explained 13% of the variation in the fish data set (i.e. redundancy = 13%). CCA1 revealed that during warmer months ($r = 0.58$), systems with longer channels ($r = 0.79$) and greater mangrove area ($r = 0.68$) had greater biomass of *Liza subviridis* ($r = 0.54$) but lower biomass of *Herklotsichthys castelnaui* ($r = –0.75$) (Table 3a). Systems with greater mangrove area coincided with greater biomass of *Leiognathus equulus* and *Escualosa thoracata* (CCA2). *Nematalosa come* was more prevalent at sites with reduced mangrove area. Variables correlated with CCA3 indicated that during cooler months, sites situated downstream in the estuaries had greater numbers of *Ambassis vachelli* and *Strongylura strongylura.*

51 mm nets. In systems that had less mangrove area and shorter channel length, research teams netted greater biomass of *Valamugil cunnesius* (CCA1, Table 3b). The opposite conditions coincided with greater biomass of *Liza subviridis.* Where mangrove area was intermediate, greater biomass of *Arius* spp. and *V. cunnesius* occurred (CCA2). For CCA3, several species were more prevalent under lower-temperature and higher-salinity conditions (winter dry season), including *Liza subviridis, Thryssa hamiltonii* and *V. cunnesius.* When temperatures were higher and salinity lower, greater biomass of *Valamugil buchanani* was netted. *V. cunnesius* was distributed widely among the sites, explaining its high correlation ($r > 0.5$) with all three canonical correlation factors.

102 mm nets. Only two significant roots were identified in the canonical correlation analysis. Upstream sites had greater biomass of *Arius* sp., but *Liza vaigiensis* was more prevalent downstream (CCA1, Table 4a). Greater biomass levels of the two polynemid species *Eleutheronema tetradactylum* and *Polydactylus macrochir* were correlated with lower temperature and higher salinity conditions at upstream sites in systems where mangrove area was within mid to higher ranges (CCA2).

152 mm nets. Greater biomass of *Lates calcarifer* occurred in systems with greater mangrove area ($r = 0.41$) that were closed to fishing ($r = –0.83$) (CCA1, Table 4b). In fact, fishing had a negative influence in all three canonical roots, although to a much lesser degree ($r_{CCA2} = –0.27$; $r_{CCA3} = –0.30$). Greater biomass of *Carcharhinus leucas*, *Eleutheronema tetradactylum*, *Pomadasys kaakan* and *Scomberoides commersonianus* occurred in systems with longer channels and higher salinity (CCA2). CCA3 indicated that biomass of *Arius* sp. and *C. leucas* was greater in areas with less mangrove coverage when temperatures were higher. *C. leucas* occurred ubiquitously and was therefore correlated with all three canonical roots ($r > 0.38$). Thus, fishing, along with the other correlated variable, mangrove area, had a strong influence on biomass of *Lates calcarifer*. Estuaries with longer channels had greater biomass of several other species of fishery importance, including *Eleutheronema tetradactylum, Pomadasys kaakan,* and *Scomberoides commersonianus.*

DISCUSSION

Biomass comparison

Owing to removal of substantial components of fish communities by fishing operations, riverine estuaries closed to commercial net fishing had 4 times greater relative biomass of larger fishes (as netted in 152 mm nets) than comparable systems open to commercial netting ($p < 0.0001$). These results agree with the conclusions reached in comparative investigations from several reef ecosystems: biomass levels of target species within marine reserves averaged between 2.2 and 7.6 times greater than levels on reefs open to fishing (Russ 2002). Our results are also consistent with the only published study that has quantified effects of reserve designation in an estuarine ecosystem: the relative abundance of gamefish in the subtropical reserve was 2.6 times greater than in nearby fished areas (Johnson *et al.* 1999). Our results support the conclusion that aquatic reserves can conserve stocks of target species, extending this concept to tropical mangrove-dominated systems under a variety of estuarine conditions.

At the species level, biomass of *Lates calcarifer* (barramundi), the main species targeted by commercial fishing operations, was more than 4 times greater in closed systems. Recreational anglers also favour barramundi as a sport and food fish (Kailola *et al.* 1993). *L. calcarifer* is a common species in tropical estuaries of northern Australia and is well adapted to the wide range of conditions characteristic of these habitats (Kailola *et al* 1993; Williams 1997). Individual barramundi tend to reside in the same estuary throughout their life cycle, although limited migration of individuals to other systems has been documented (Russell and Garrett 1987). Probably as a result of the ubiquitous distribution of *L. calcarifer*, we were able to detect a significant and consistent difference between open and closed systems for this species. Two other popular commercial and recreational species that dominated the biomass netted in larger-mesh nets (*Eleutheronema tetradactylum* blue threadfin and *Scomberoides commersonianus* queenfish) tend to occupy a range of marine habitats during their life-history cycles, moving in and out of estuaries under particular conditions or times of year (Williams *et al.* 1997; Kailola *et al.* 1993). Although our results indicated that patterns of habitat use by such species as blue threadfin and queenfish were skewed towards particular sites, all of the estuaries having high biomass of these species were closed to commercial net fishing. Clearly, the designation of aquatic reserves protected from commercial fishing serves as a conservation benefit to species of fishery interest in the region.

Relative biomass of smaller fishes (as netted in 19–51 mm research nets) did not appear to be influenced by fishing closures. In several studies of coral reef fish communities, results were similar to ours: a reduction in target species did not correspond with any notable differences in populations of other fish species (Jennings and Kaiser 1998). In freshwater systems, strong cascading effects on small fish assemblages, apparently triggered by removal of top predators, have been empirically demonstrated (Power 1990; Carpenter *et al.* 1985). Owing to a variety of factors, indirect effects of fishing on prey fish in marine and estuarine habitats may be less pronounced than in other habitats. For example, the difference in the number of predators between open and closed systems may not have been great enough to generate detectable differences in relative biomass of their main prey items. Bottom-up effects may have a greater influence on productivity of these forage-base species than top-down effects due to predation (Ley *et al.* 2002).

Spatial variation in fish assemblages

Effects of commercial fishing closures on species assemblage patterns were only observed for biomass caught in the largest-mesh research nets (152 mm). Furthermore, each estuary had a unique fish assemblage that remained consistently distinct among seasons, as indicated by the MDS analysis. Even at a more general taxonomic level, not all systems were dominated by the same families. Whereas Centropomidae dominated four of the estuaries, Polynemidae and Ariidae dominated the other two. From the arrangement of samples in the MDS diagrams, it was apparent that similarities between estuaries were not simply a function of latitudinal gradient; this indicated the strong underlying influence of other habitat variables. Our results are consistent with an investigation in which traps were used to sample fishes in three mangrove tidal creeks less than 150 km apart within our study area (Sheaves 1998). In terms of fish assemblages sampled, he found that the three tidal creeks were distinct entities. Similar trends were noted in a comparison of four estuaries spanning a much larger region around the Gulf of Carpentaria, in which multiple gear types were deployed to gain a more comprehensive picture of estuarine fish communities (Blaber *et al.* 1994). The overall pool of species in the Gulf region was considered to be homogeneous, but each system had unique species assemblages. These results support the idea that unique species-assemblage patterns found in estuaries result from differences in underlying habitat features and not simply from biogeographical gradients.

Species and habitat variables

Commercial fishing was among the most significant habitat factors influencing biomass of leading species caught in our largest-mesh nets (152 mm). Fishing was a strongly correlated factor (r = 0.83) for *Lates calcarifer*, overriding the influence of mangrove area (r = 0.41). Fishing also negatively influenced the biomass of other species caught in these nets, including *Carcharhinus leucas*, *Eleutheronema tetradactylum* and *Scomberoides commersonianus*, but to a much lesser degree than the other ecologically significant variable, channel length (r = 0.89). Thus, whereas fishing had a primary influence on catch biomass of *L. calcarifer*, it had a secondary influence on the other three species that dominated the catch in the 152 mm research nets. To our knowledge, only one other study has quantified relationships between habitat and fish assemblages in reserve and non-reserve estuaries. Fishing was the most important factor, but salinity and water depth also strongly influenced overall catch rates of gamefish in a subtropical Florida system (Johnson *et al.* 1999); the importance of habitat factors varied with each individual gamefish species tested. Our results are consistent with conclusions reached by the Florida investigators: in most cases, each canonical root described the correlation between only one or two species and a set of habitat variables. Thus, while trends in biomass for most species (except *L. calcarifer*) were weakly related to fishing, each displayed individualised correlations with the habitat factors analysed.

The most influential variable in the CCA analysis was index of mangrove area. Thus, species tended to be distributed among the sites along a gradient of mangrove area, a relatively stationary habitat variable. Relatively few relevant investigations have been conducted in mangrove habitats, but many studies have related features of habitat structure to reef fish assemblages. Evidence from coral reefs suggests that consistent relationships exist between habitat structure and fish assemblages at the broader scale of physiographic zones, as generated by depth, broad shape and size, and exposure gradients (Sale 1991). Similarly, particular species were uniquely associated with one of several general substratum types (boulder, mud, rock ridge) in deep rocky reefs surveyed by divers in a submersible (Stein *et al.* 1992). Likewise, well developed mangrove forests on small peninsulas extending into deeper water supported distinctive fish assemblages of lutjanids and haemulids in Florida Bay (Ley and McIvor 2002). Thus, our results are consistent with the concept that broadscale habitat factors can be influential determinants of fish habitat use in a variety of habitats. The main structuring factors for coral and rocky reefs – hard rugged substratum with high vertical relief – may be functionally equivalent to development of spatially extensive areas of mangrove root habitat in tropical and sub-tropical estuaries.

Estuaries tend to be more dynamic than tropical and deep-reef habitats in physico-chemical conditions such as salinity, temperature, pH, turbidity and tidal influence. In our study, temperature and salinity were influential variables in 6 out of the 11 canonical roots. Salinity, temperature and water depth interacted in complex seasonal patterns coincident with particular assemblages of fishes across the estuarine gradient in Florida Bay (Ley *et al.* 1999). In subtidal mangrove habitats, salinity regime was correlated with species distributional patterns, but turbidity and temperature were not (Sheaves 1998). Another tropical multi-estuarine study suggested that species distributional patterns may be strongly influenced by current speed and turbidity and to a lesser extent by salinity (Blaber *et al.* 1994). Given such divergent results, further investigation is clearly needed to quantify underlying relationships with appropriate scale, replication and duration within estuaries.

In the present investigation, dynamic and stationary habitat features were significantly correlated with subsets of fish species, but the magnitude of variation in fish assemblages explained by habitat variables was low (8–14% redundancy). Inclusion of other important factors such as productivity and substratum variables in habitat measurements may have improved the identification of explanatory conditions. Comprehensive surveys of the type conducted in the present study may serve to more clearly define the relationships between fish species and their habitat.

Implications for aquatic reserves

Estuaries in close proximity to each other differ substantially in habitat attributes and associated fish assemblages. In our study, even along a relatively short distance of coastline (400 km), fish communities varied greatly among the systems, at least partially as a result of differences in estuarine morphology and aquatic conditions. Similarly, in demersal habitats on the south-eastern Australian continental shelf, a combination of substratum complexity and hydrodynamic factors were apparent determinants of habitat use by particular species of fishery importance (Williams and Bax 2001). As suggested by Browder and Moore (1981), these two types of variables (stationary structure and dynamic aquatic conditions) set the stage for determining the types of fish assemblages found within a given system. Managers may ask, 'Can broad-scale physical attributes such as these be used to define priorities for establishing aquatic reserves that maximise ecological and fishery benefits?'. The present study indicates that the answer would be '*yes*'. Similar conclusions were reached for fully marine habitats in temperate south-eastern Australia (Ward *et al.* 1999). However, on the basis of the apparent habitat specificity among important fishery species, only a network representing a range of systems will serve the goal of conserving regionally diverse fisheries. Networks could also reduce the region-wide risk of anomalous effects on a single reserve and increase the potential benefits to non-reserve areas by increasing the connectivity between protected and non-protected areas (Allison *et al.* 1998; Murray *et al.* 1999; Hixon 2002). In other words, to conserve a diversity of estuarine fishery species, a diversity of estuarine types must be designated through a regional approach. Surveys such as the one described in this paper can provide the basis for comprehensively setting priorities for designation of sites under a network approach to aquatic reserve designation.

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OPTIONS FOR THE PROTECTION OF FRESHWATER ECOSYSTEMS AND THE SERVICES THAT SUSTAIN HUMAN LIFE

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Abstract

Freshwater ecosystems represent an extraordinary proportion of the world's biodiversity and are vital for the sustenance of human life. Yet freshwater ecosystems remain one of the most threatened habitats in the world. Half of the world's wetlands have been destroyed in the past 100 years; in some regions of Australia this figure is as high as 85%. Despite this clear conservation imperative, the use of protected areas to conserve biodiversity is less advanced in fresh waters than in terrestrial and marine environments. Owing to the size of many freshwater ecosystems and their catchments, they commonly cross ownership and jurisdictional boundaries. This creates complexities in achieving their protection, a situation that is exacerbated by their occurrence across the transition from inland to coastal and marine waters.

It is often difficult to classify and delineate freshwater ecosystems for their protection and to deliver conservation at a level that matches the scale of the issues being faced. This paper points to policy tools that are in use, globally and in Australia, for the protection of freshwater ecosystems, the Ramsar Convention offers an effective tool with which to build and maintain a network of freshwater ecosystems. Although some seek new legislative options to protect Australian freshwater ecosystems, particularly rivers, a framework already exists under the *Environment Protection Biodiversity Conservation Act 1999;* it is time, not to create new tools, but to apply those that already exist. The wetlands of Lake Chad and of the Gwydir catchment, Australia, demonstrate the use of Ramsar Protected Areas as a catalyst for sustainable management at a catchment scale.

Keywords: Ramsar, freshwater, protected, river, management

INTRODUCTION

Freshwater ecosystems represent an extraordinary proportion of the world's biodiversity. These systems are also vital for the sustenance of human life through the ecological and hydrological functions they perform. Yet freshwater ecosystems remain one of the most threatened habitats in the world. It has been estimated that half of the world's wetlands have been destroyed in the past 100 years (IUCN 2000). In some regions of Australia this figure is as high as 85% (McComb and Lake 1990). Despite this clear conservation imperative, the use of protected areas to conserve biodiversity is less advanced in fresh waters than in terrestrial and marine environments.

The factors contributing to this situation include:

1. The size of many wetland ecosystems and their catchments, commonly across a number of ownership and jurisdictional boundaries, creates legal and social complexities in achieving their protection.
2. These systems occur across the transition from inland to coastal and marine waters and the limnological change (be it biological, physical or chemical) on either a cyclical or an irregular basis that is an intrinsic feature of many wetland systems. This creates challenges for any attempt to broadly classify and delineate wetland ecosystems for their protection, and to deliver conservation at a level that matches the scale of the issues being faced (Paijmans *et al*. 1985).
3. The perception that separates the water resource use and the wetland ecosystems that provide this source of water is often reflected at a decision-making level in some jurisdictions by the direct division between water allocation decisions and catchment management decisions.

At this point, clarification needs to be made regarding the use of the words freshwater and wetland. In the text of this paper, the two words are used interchangeably although it is recognised that the word wetland, in particular, means different things to different people (Phillips 2001).

In Australia, for example, the federal Wetlands Policy adopts the Ramsar Convention's definition of wetlands and then qualifies it by excluding some wetland types, such as rocky shorelines and the main in-channel elements of permanent rivers and streams. Those States and Territories with either wetland policies or strategies have followed a similar route: acknowledging the Ramsar Convention's definition and then qualifying it in some way. Curiously, there is a Floodplain Wetland Strategy for the Murray–Darling Basin that takes a definition of wetland different to that used by the Basin's member State Governments and the federal Government.

When the term wetland is used, it follows the Ramsar Convention's context although rivers and coastal environments are also included:

> *"areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6m." And "may incorporate riparian and coastal zones adjacent to wetlands, and islands or bodies of marine water deeper than 6m at low tide lying within wetlands."*

WETLAND CONSERVATION OPTIONS

The question for the Australian community to decide is "What should a system of freshwater or wetland protected areas look like?" However, for any such system to make a difference, it clearly would need to constitute a coherent and comprehensive national network of wetlands that are important for the conservation of biological diversity and for sustaining human life through the ecological and hydrological functions they perform.

The tools available to create and maintain such a system are diverse. At the global level, a range of treaty options provides a framework for the protection of wetland environments. These options include:

- the Convention on Wetlands of International Importance (the Ramsar Convention);
- the Convention on Biological Diversity;
- the "Man and the Biosphere";
- the Bonn Convention;
- bilateral and multilateral agreements for the protection of habitats for migratory species; and
- the World Heritage Convention.

When options for the creation of a system of freshwater protected areas are sought, the role of international treaties should not be underestimated, especially in Australia, for the following reasons:

- Treaties establish international environmental standards that set the norms our institutions are morally obliged to adopt; and
- Under Australia's constitution, the Federal Government can use its 'foreign affairs power' to intervene at the State/Territory level to conserve attributes that it has an international obligation to conserve.

In an Australian context these options are supported by, or translated into, a range of policy and legislative options including:

(a) the federal *Environment Protection and Biodiversity Conservation Act 1999*, which came into force on 16 July 2000 (WWF Australia and HSI 2000). This legislation enables, for the first time, federal regulation of

- Sites,
- Species,
- Ecological Communities,
- Key threatening processes,
- Invasive Species and
- Heritage (proposed).

The Act provides a new regime for the listing, protection and management of Ramsar wetlands. Any proposed action that has, or is likely to have, a significant impact on the ecological character of a declared Ramsar site will trigger the federal environmental assessment and approval processes, even in State or Territory jurisdictions, including relevant actions occurring in a wetland's catchment.

(b) Programmatic measures

Treaties also encourage member nations to adopt national strategies and frameworks to implement their provisions, for example

- Indigenous Protected Areas;
- Land for Wildlife; (need to keep capitals as are the names of Programmes)
- Man and the Biosphere Reserves program;
- Environmental protection policies;
- Conservation Management Networks program;
- State/Territory Government conservation agreements;

- Memorandum of understanding between the landholder and jurisdictional governments that is recognised as either a "contract" or a less rigorous "statement of intent" (which can then include other stakeholders) and a management plan;
- State and federal reserve systems.

Of these options, to which Governments are already committed and contributing considerable resources, the Ramsar Convention offers a most effective tool with which to build and maintain a network of protected areas for freshwater ecosystems.

The Ramsar Convention is an international convention that was signed in Ramsar, Iran in 1971. It provides the framework for national action and international cooperation for the "conservation and wise use of all wetlands" and their resources – where 'wise use' means "sustainable utilisation for the benefit of mankind in a way compatible with the maintenance of the natural properties of the ecosystem."

The 132 countries that have joined the Convention have designated 1178 Wetlands of International Importance, otherwise know as Ramsar sites. At present, Australia has 57 designated Ramsar sites. These are places of special global, ecological or hydrological value and collectively form a global network of demonstration sites for sustainable wetland use. Therefore, the Ramsar Convention has a practical impact in many countries.

It is the emphasis on wetland use that makes the Ramsar Convention so different from the World Heritage Convention. World Heritage effectively aims to identify and protect "jewels in the world's crown" whereas the Ramsar Convention recognises and maintains wetlands and the vital services they provide. It's about people using their wetlands. Two case studies are described below; they demonstrate the use of the Ramsar Convention to achieve the conservation of biodiversity and the sustenance of human life through the functions these wetlands support.

CASE STUDY 1: LAKE CHAD, AFRICA

The use of the Ramsar Convention has stimulated an unprecedented whole-of -catchment management; protected-area establishment for Lake Chad in Africa is a case in point. Lake Chad is Africa's fourth-largest body of water and supports more than 20 million people in four countries: Chad, Cameroon, Niger and Nigeria. It is commonly called the "shrinking lake" and is recognised as one of Africa's most endangered wetlands. In the past 40 years, Lake Chad has shrunk by up to 80%. In 1960, Lake Chad covered about 25 thousand sq km, whereas now it covers only 2000–9000 sq km, depending on the volume of rainfall in a given season.

Those living around Lake Chad's shores lack access to safe drinking water and proper sanitation. They are also challenged by invasive meadows of grass, covering up to half of the lake's surface, which make navigation impossible, thus impeding the transport of goods that sustain the region's economy. The situation is exacerbated by unsustainable water management, including dyke building, and the lack of proper irrigation systems and resulting salt accumulation in the soil.

In July 2000, Heads of State from Cameroon, Chad, Niger, Nigeria and the Central African Republic gathered to discuss options for managing the lake. The then Executive Secretary of the Lake Chad Basin Commission (LCBC), Abubakar Jauro, expressed his hopes for rescuing Lake Chad from unsustainable management compounded by climate change, desertification and invasive grasses.

On 17 June 2001, Niger declared the designation of 340,000 ha of the Nigerian part of the lake as a wetland of international importance. On 14 January 2002, the Chadian part of the lake (covering 1,650,000 ha) was formally designated as a wetland of international importance. These commitments were founded on common agreement on what was at stake and what needed to be done.

In becoming the first trans-boundary wetland declared as a Ramsar site in Africa, it

- extended the understanding among neighbouring nations that the Ramsar Convention is an international instrument under which governments commit to conserving their water bodies, which supply water, food and material;
- channelled international funding (Global Environmental Facility) into pilot projects and management plans in the Lake Chad region;
- by virtue of all projects being trans-boundary, enhanced cooperation among villagers and whole communities in establishing laws and programmes to conserve the Lake;
- involved the work of the LCBC as a local managing body – this was vital because the Commission acts as an instrument for governing shared resources, promoting dialogue among countries and avoiding unnecessary conflicts over their use;
- made a valuable contribution to Africa's network of freshwater protected areas, over a large area, that is used in a variety of ways by diverse cultures; and

- made available tools essential to raising awareness of wetland values; these tools range from brochures, maps and posters to web services and web-based outreach programmes.

CASE STUDY 2: GWYDIR WETLANDS, AUSTRALIA

The Ramsar Convention has been used as a community-based tool for the implementation of integrated management of a river basin at the sub-catchment scale. It is an example highly relevant to (coastal and estuarine conservation in which listing of a downstream site has been used to extend legal protection to the catchment.

In Australia, the onus has largely rested with State governments to address wetland conservation imperatives, but despite significant outcomes the rate of wetland degradation has not been halted or reversed. Designation of wetlands in the conservation estate has not always guaranteed stewardship by local communities and the private sector. This is important, given that 70% of land area is under the control of private landholders and resources managers, including indigenous people (Georges and Cottingham 2002).

There is, however, a new era emerging in wetland conservation in which local communities, governments and the private sector work in partnership to achieve common objectives; the Gwydir, a major tributary of the Darling River, offers one such example.

The Gwydir River system has a 200,000 ha inland delta wetland. Soon after the Copeton Dam was completed upstream in 1976, 118% of dam capacity was allocated for irrigated agriculture. There was a dramatic decline in breeding of nationally significant waterbird populations, because they would breed only following floods, and over 50% of the wetland area had been lost. The livestock-carrying capacity of the floodplain pastoralists declined by up to 73%.

WWF Australia and the New South Wales National Parks Association negotiated an agreement with four pastoralists for nomination of nearly 1000 ha of Gwydir wetlands for Ramsar listing on 2 February 1999. This was the first voluntary nomination in Australia of privately managed land for conservation under an international treaty. The listing triggers application of the national *Environment Protection and Biodiversity Conservation Act* to conserve the ecological processes that sustain the wetlands.

Owing to the increased profile and legal protection of the wetlands, WWF and the pastoralists were able to agree with the local Gwydir water management committees to

- return some allocated water for environmental flows,
- store water for release to complete waterbird breeding events; and
- allocate half the water from an unregulated tributary to the wetlands to maintain natural variability.

Consequently, around 500,000 waterbirds returned to breed in three subsequent flood events in the wetlands and the carrying capacity for pastoralists' livestock improved.

For the private landowners, Ramsar designation of their wetlands was of benefit because it provided

- public acknowledgment of their good wetland management,
- greater livestock productivity,
- greater priority for funding for public-good activities,
- access to information and technical support,
- opportunity to mitigate upstream threats using the national environmental law,
- greater priority for help from other government programmes, e.g. monitoring agricultural chemical levels, and
- clarification of their legal obligations under State and Federal legislation.

For sustainable river-basin management, this work was of benefit because it provided

- good management of wetlands that may never be included in government-owned conservation reserves,
- mitigation of threats, especially from upstream use, by use of the national law;
- greater priority for help from other government programmes, e.g. for salinity mitigation,
- development of a positive relationship between conservation agencies and a rural constituency, and
- conservation achieved by landowners at a lower cost to the public purse.

ADVANCES IN STRATEGIC IMPLEMENTATION OF THE RAMSAR CONVENTION

Most Ramsar sites have been declared more on serendipity than on sound science. As a result, in 1999, at the 7th Conference of the Contracting Parties a "*Strategic framework and guidelines for the future development of the List of Wetlands of International Importance*" was adopted. As part of this framework 132 countries around the world, including Australia, stated that their vision is

"To develop and maintain an international network of wetlands which are important for the conservation of global biological diversity and for sustaining human life through the ecological and hydrological functions they perform."

The guidelines supporting this vision further state that

"Such an international network of wetland sites has to be built from coherent and comprehensive networks of Wetlands of International Importance within the territory of each Contracting Party to the Convention."

Together, these two statements provide a challenge for each Party of the Convention to set about interpreting and applying them within the national context. They also provide the potential for an effective planning instrument for each protected area.

CONCLUSION

In Australia, although we could seek new legislative options under the *Environment Protection and Biodiversity Conservation Act 1999* to protect Australian freshwater ecosystems, we already have an option that offers a framework for a coordinated conservation response that engages all landholders.

Ramsar listing of wetlands is flexible in its application, is relevant to different land tenures – which is vital given the range of tenure and property-right considerations that apply to wetland environments – and encompasses all wetland types present in Australia, including rivers. This latter point is worth noting because there is a far more narrow view in many Australian circles of what habitat types the Ramsar Convention covers, expressed by policy decisions to exclude rivers from its scope in Australia (see above). This decision is not reflected in the implementing legislation for the Convention – the *Environment Protection and Biodiversity Conservation Act 1999*. The view that Ramsar does not apply to rivers is out of step with the Convention and its global initiatives regarding river basins.

Although the Ramsar Convention recognises marine waters as 'wetland', this definition is still debated in Australia. Hence, Australia's coastal habitats do not benefit from this conservation tool at present.

Ramsar listing offers the opportunity to:

- design strategies that protect physical processes, particularly hydrologic processes operating over large spatial scales,
- address the importance of connectivity within and between aquatic habitats, the riparian zone, floodplains and subterranean systems,
- allow for the specific protection of undisturbed habitats,
- address the impact of land uses within the larger catchment (this element could be strengthened further by altering the *Environment Protection and Biodiversity Conservation Act* to provide for the **compulsory** development of catchment plans for Ramsar wetlands), and
- address downstream impacts that begin upstream.

There are options for wetland conservation and it is time to expand the use of the Ramsar listing option.

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FRESHWATER RESERVES IN NEW SOUTH WALES, AUSTRALIA: A POWERFUL BUT UNUSED TOOL FOR CONSERVING FRESHWATER BIODIVERSITY

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Abstract

No aquatic reserves exist in freshwater rivers or creeks of Australia, and no process or timetable exists for their establishment. This is despite the existence of adequate legislation and a number of policy imperatives. Reasons for the lack of progress towards establishing these reserves include departmental segregation and the resulting ownership issues, as well as lack of resource commitment, and land tenure issues. The Inland Rivers Network believes that the formation of a interagency working group on freshwater aquatic reserves, as well as the use of voluntary conservation agreements, will enable these impediments to be largely overcome. National and international case studies also support this. The paper examines potential FAR objectives, selection criteria and management options.

Keywords: freshwater reserves, Australia, recommendations, legislation

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INTRODUCTION

The ecological imperative for improving river and catchment management in New South Wales is compelling:

1. The *NSW Rivers Survey* (Harris and Gehrke 1997) found stocks of native fish in New South Wales to be generally in a degraded state, with poor biodiversity in many inland regulated rivers. Many once-common species had become regionally extinct across vast areas of their former range, such as silver perch. Introduced species such as carp and trout were widespread and abundant;
2. Seven species of New South Wales native fish in inland and coastal waterways are listed, or are in the process of being listed, as threatened on Schedule 5 of the *Fisheries Management Act* (see Table 1);
3. The aquatic ecological community of the regulated reaches of the Murray, Murrumbidgee, Edwards and Wakool rivers has been listed as an endangered ecological community under the Act;
4. The New South Wales State of the Environment Report 2001 states that "Freshwater rivers in NSW may be the most degraded ecosystems in large part due to the impact of river regulation from dams and weirs… [and]… there is very little formal protection for freshwater ecosystems compared with terrestrial ecosystems" (EPA 2000);
5. A report (Morris *et al.* 2000) has concluded that habitat degradation, changes to water flow regimes, barriers to fish passage, the introduction of alien fish species, and fishing pressure have caused significant declines in the diversity and abundance of native fish in the Murray–Darling Basin.

Freshwater Aquatic Reserves (FARs) would provide important protection for aquatic habitats and fish, and would also be a useful management tool for assisting the recovery of threatened fish species and ecological communities listed under the *Fisheries Management Act 1994* (NSW) (FM Act). Provisions for aquatic reserves exist within the FM Act (Part 7 Division 2) and may be applied equally to fresh waters as to marine and estuarine areas. But although eight marine and estuarine aquatic reserves or interim protected areas exist in NSW, and another 22 marine and estuarine aquatic reserves are being proposed, no FARs exist in NSW (NSW Fisheries 2001). The lack of FARs is all the more noteworthy given that terrestrial and marine reserves are seen as the 'jewels in the crown' of biodiversity conservation efforts in their respective environments. Yet even the current draft *NSW Aquatic Biodiversity Strategy* perpetuates this failure to provide for the establishment of a CAR system of FARs despite the widely acknowledged stresses facing freshwater ecosystems.

Table 1. Threatened fish species listed on Schedule 5 of the *Fisheries Management Act 1994*. The probable causes of decline, as identified by The NSW Fisheries Scientific Committee, are listed for each species. V, vulnerable; E, endangered. (Source: Fisheries Scientific Committee: www.fsc.nsw.org.au, Koehn and O'Connor 1990; Wager and Jackson 1993; Lintermans 2000)

Fish species	**Trout cod**	**Murray hardyhead**	**Purple spotted gudgeon (Western pop.)**	**Olive perchlet (Western pop.)**	**Silver perch**	**Macquarie perch**	**Southern pygmy perch**
Fisheries Management Act 1994 (NSW) status	**E**	**E**	**E**	**E**	**V**	**V**	**V**
Habitat degradation	*	*	*	*		*	*
Barrier to fish passage		*	*		*	*	
Alteration to flow regime	*		*	*	*		*
Desnagging	*						
Exotic species	*	*	*	*	*	*	*
Thermal pollution	*	*		*		*	*
Pollution (sediments, nutrients)	*						
Overfishing	*					*	

Trout cod: *Maccullochella macquariensis*

Murray hardyhead: *Craterocephalus fluviatilis*

Purple spotted gudgeon: *Mogurnda adspersa*

Olive perchlet: *Ambassis agassizii*

Silver perch: *Bidyanus bidyanus*

Macquarie perch: *Macquaria australasica*

Southern pygmy perch: *Nannoperca australis*

CONSERVATION STATUS OF FRESHWATER FISH IN INLAND NSW

The *NSW Rivers Survey* demonstrated the generally poor state of native fish stocks, with almost one-third of species known to have occurred in NSW rivers not recorded over the two-year study (Harris and Gehrke 1997). Species once considered widespread and relatively common were found either to have restricted distributions or to be absent from large areas. Six species and two populations are now listed as threatened in NSW under the FM Act (Table 1), as well as the recent listing of an entire aquatic ecological community as endangered.

Reasons for lack of progress in establishing FARs

There appear to be several contributing factors to inaction over the creation of FARs:

1. The heterogeneous nature of land tenure along rivers, with most ownership being private, and the statutory requirement of landholder consent for an aquatic reserve to be declared. The majority of riparian lands and river beds are privately owned;
2. The nature of rivers and the inability of a FAR to directly prevent or regulate upstream activities which adversely affect aquatic biodiversity and habitat within a FAR;
3. Historical unwillingness of NSW Fisheries and the NSW Government to institute changes that may affect landholders (owing to perceived and real reticence of landholders towards a reserve and restrictions on their ability to use a river) and impose further significant restrictions on recreational angling access to rivers;
4. Potential costs of compliance strategies and reserve management strategies;

5. Concern within NSW Fisheries as to the costs of establishing FARs, particularly purchasing private land along river banks if found to be necessary;
6. The complexity of reserve site selection, in large part due to the movement of native fish along a river and potentially from inside to outside a FAR (although the same argument can be made in relation to terrestrial and marine reserves);
7. Failure of NSW Fisheries to commit sufficient resources and staff to complete preliminary investigations into FARs; and
8. High turnover of NSW Fisheries staff in regional areas, which has undermined the development of the long-term working relationships between fish conservation staff and other river stakeholders that are requisite in effecting FARs on the ground.

The Inland Rivers Network appreciates that many obstacles exist to establishing a system of FARs. Nevertheless we consider FARs to be necessary and potentially highly effective tools in conserving aquatic habitat and biodiversity (a key objective of the FM Act). Problems of a similar nature to those detailed above have been overcome in establishing terrestrial and marine reserves, and Ramsar wetland sites, and in several effective international working models for freshwater habitat protection. Further, State, national and international legislation and agreements provide a strong rationale and basis for establishing FARs.

Fisheries Management Act 1994 (NSW) (FM Act)

The objectives of the FM Act are to "conserve, develop and share the fisheries resources of the state [of NSW] for the benefits of present and future generations" (s.3). In particular, the objectives include conservation of fish stocks and protection of key habitat, and conservation of threatened species, populations and ecological communities[1] of fish (Part 1(3)).

The Act was amended in 1997 and 2001, and so now includes provisions relevant to threatened species and protection of their habitat, and provisions for the production of management plans for aquatic reserves. It also contains requirements for the preparation and implementation of recovery plans and threat abatement plans for species (Smith and Pollard 1999).

[1] 'species' will now be used to refer to 'species, populations and ecological communities'

Part 7, Division 2 of the *Fisheries Management Act 1994 (NSW)* provides an adequate framework for the establishment of aquatic reserves in fresh water to enhance the protection of fish and fish habitat, through the protection of significant habitat and for the conservation of threatened species (Smith and Pollard 1999). Section 194(2) states that 'The purpose of declaring an area to be an aquatic reserve is to conserve the biodiversity of fish and marine vegetation and, consistently with that purpose:

(a) to protect fish habitat in the reserve, or

(b) to provide for species management in the reserve, or

(c) to protect threatened species, populations and ecological communities in the reserve, or

(d) to facilitate educational activities and scientific research.'

The regulations relating to aquatic reserves may:

(a) prohibit or regulate the taking of fish or marine vegetation from aquatic reserves, and

(b) provide for the management, protection and development of aquatic reserves, and

(c) classify areas within an aquatic reserve for different uses (such as recreational uses or as a sanctuary) (Section197).

Aquatic reserves can be declared over any land or waters, provided consent has been gained by the Minister from the landholder (when private land is involved) or relevant department (for and area of public water or land) (Section195). NSW Fisheries declare aquatic reserves for various reasons, including the "protection and management of important habitat for commercially and recreationally important species" (MPA 2000). The establishment of aquatic reserves will necessitate significant consultation with landholders and public authorities. Further, the provisions enable zonation within aquatic reserves, allowing a measure of management flexibility.

The FM Act also includes provisions for Habitat Protection Plans (HPPs) (Part 7, Division 1) and critical habitat. The former are particularly valuable to guide administrative decision-making, and could be used to complement a FAR. However, existing HPPs do not provide adequate regulatory tools for the task of rehabilitating freshwater rivers.

No critical habitat has been declared in NSW under the FM Act. This is probably due to the fact that its scope is limited to the protection of *endangered* species, and it may be imposed on private land with minimal consultation (Section 220R). Accordingly, the declaration of critical habitat is not the preferred method of establishing aquatic protected areas, with the aquatic reserve framework generally proving a more suitable form of protection.

Policy imperatives

The creation of a comprehensive, adequate and representative (CAR) reserve system forms a core component of biodiversity conservation (CoAG 1992). The *Intergovernmental Agreement on the Environment 1992* (IGAE) between the Australian federal government and States explicitly provides for the establishment of aquatic reserves in freshwater systems (see Item 13) (Commonwealth of Australia 1992). Further, both the *NSW Biodiversity Strategy* (Objective 2.2) and the *National Strategy for the Conservation of Australia's Biological Diversity* (Objective 1.4) provide a policy imperative for the establishment of a CAR reserve system for the protection of biological diversity, including freshwater biodiversity.

The National Reserve System (NRS) provides a mechanism for the establishment of a CAR freshwater reserve system. Through the NRS a biogeographic regionalisation approach has been adopted for terrestrial and marine reserve systems, but none have been developed explicitly for freshwater ecosystems. Further, no money has yet been allocated through this program to support the establishment of freshwater reserves (Nevill 2001).

International obligations

Article 8 of the UN Convention on Biological Diversity calls for contracting parties to establish a system of protected areas to conserve biological diversity. In addition, the International Convention on Wetlands 1971 (the 'Ramsar Convention') requires Australia to undertake special measures to ensure protection of the important values of a Ramsar-listed wetland. Yet, after 30 years, Australia has fulfilled only part of its obligations under the Convention, since comprehensive wetland inventories and comprehensive national reserve systems remain incomplete (Nevill 2001). Under the *Selected Criteria for designating Wetlands of International Importance under the Ramsar Convention on Wetlands* there are two criteria that apply specifically to the protection and management of fish and fish habitat, and one that provides for the protection of threatened species and communities. Neither of these criteria has been adequately recognised in freshwater systems. In part this is due to the limiting definition adopted in Australian policies. The definition of "wetlands" used in the Ramsar convention encompasses **all** freshwater ecosystems, and so includes all flowing waterways, such as rivers and streams, whereas Australian policies exclude such water bodies, including only areas with slow or stationary water (Nevill 2001). For Australia's Ramsar obligations to be fulfilled, programs need to be developed covering all ecosystems that are encompassed by this definition.

NSW Aquatic Biodiversity Strategy

The *NSW Biodiversity Strategy 1999* states that the development of a system of freshwater reserves is to be addressed by the *Aquatic Biodiversity Strategy*, currently being drafted by NSW Fisheries (as an additional component to this Strategy) (NSW Fisheries 2001). Unfortunately, the draft Aquatic Biodiversity Strategy fails to commit to a system of FARs. This is despite an earlier draft stating that the establishment of freshwater reserves is "a key component" in the conservation of inland biodiversity.

CASE STUDIES

International experiences

Several freshwater protected areas have been successfully designated in Canada. In two ecological reserves, fish populations are protected as all consumptive uses are prohibited (Morrison *pers. comm.* 2001). In British Columbia parks that include freshwater systems, legislative provisions provide habitat protection and require activity restrictions such as a zero retention of certain species and reduced modes of access.

In some situations voluntary agreements have been used to overcome reticence by landholders. Some provinces have taken a 'protection by example' approach to encourage public participation (Environment Canada 2001). This has been accomplished through education, provincial policies, and legislation that provides for stewardship agreements, conservation easements and covenants. For example, the Ontario *Conservation Land Act* encourages private landholders to act as stewards on natural areas through the payment of grants for the agreement, or for other benefits, such as a reduction in property taxes.

The International Union for the Conservation of Nature (IUCN) has established freshwater reserves in several countries with varying success. Wide consultation has enhanced the successful implementation of aquatic reserves, as well as use of financial incentives and the establishment of new semi-governmental institutions to deal specifically with reserve management. Reserves usually consist of a core with strictly regulated activities, surrounded by a buffer zone with less-stringent regulation (Bos, *pers. comm.* 2001).

Australian experiences

As yet, the only serious attempts at establishing freshwater reserve systems have been made by Victoria and the Australian Capital Territory (ACT) (Nevill 2001). Most other States (excluding Tasmania and Queensland) have legislation containing provisions for the establishment of FARs (Wager and Jackson 1993; and Nevill 2001). However, despite this there has been little or no State funding provision, rendering programs ineffective and commitments inadequately met.

Victoria is the only State to have formalised a riverine reserve system through legislation: the *Heritage Rivers Act 1992*, developed from a program of which one aim was to ensure the protection of representative examples of stream types. Initially it was expected that protection would be gained through Crown land management plans, land-use planning mechanisms to provide controls on private land, and in some situations formal agreements with landholders (Nevill 2001). However, no management plans have never been finalised and in some cases never even drafted.

In the ACT the full length of the Murrumbidgee River is managed primarily for nature conservation as the Murrumbidgee River Corridor, with all land along the banks linking a series of nature reserves (Lintermans 2000). This river corridor protects the riparian zones and restricts bank and river development, which in turn protects in-stream values.

Throughout Australia, voluntary management agreements (MA) are used to promote vegetation conservation on private land, and have generally achieved outstanding results despite very limited funding (Binning and Young 1997). States that have provided incentives and/or used legislation to trigger entry into agreement have proved far more successful in MA initiation (Binning and Young 1997). Financial incentives could include reimbursement of management costs, compensation for forgoneland-use opportunities, and indirect payment such as a tax reduction or rate rebate. Further, as MAs are a contract, they have the potential to prove flexible to each unique situation.

Protection of marine areas in NSW

Unfortunately, aquatic reserves in NSW have not proved very effective, because protection has been weak with very small or no sanctuary zones. A similar situation exists for marine protected areas (MPAs), where potential effectiveness has been watered down through inadequate designation of no-take zones. However, MPAs in NSW have proved somewhat more effective owing to the fact that the administrative body, the Marine Parks Authority, is under the joint management of NSW Fisheries and the NSW National Parks & Wildlife Service. Most MPAs are multiple-use with varying types and degrees of restrictions to fishing activities. Nationwide, fisheries management agencies recognise the importance and need for MPAs (Exel 1996). Studies on benefits of MPAs to ecosystems have indicated a dramatic improvement in species diversity, numbers, and general ecosystem health, demonstrating the remarkable success achievable through the establishment of protected areas. MPAs have even protected a large percentage of the population of migratory species by the protection of their aggregating sites (Otway and Parker 2000). Such protected areas are seen as an effective way to ensure that resource biodiversity is protected, whilst also allowing the sustainable use of these resources.

Establishing a system of freshwater aquatic reserves in NSW

A comprehensive, adequate and representative system of FARs should be established as a priority for the conservation of aquatic biodiversity and habitat in NSW. FARs should provide adequate protection for freshwater ecosystems spanning the range of biogeographic regions in the State (which need to be identified to provide a basis for establishing FARs).

Reserve management

The two principal agencies responsible for conserving aquatic species and habitats are NSW Fisheries and the NSW National Parks & Wildlife Service (NPWS). Possibly one of the main impediments to establishment of freshwater reserves in NSW is this departmental division. The FM Act falls within the jurisdiction of Fisheries, which will be unable to satisfactorily implement its statutory responsibilities under the Act, particularly the conservation of aquatic biodiversity and habitat, and recovery of threatened species and ecological communities, without establishing a CAR system of FARs. However, the culture of Fisheries is not conducive to the conservation of fish species. Even the legislation that provides for aquatic reserves is largely geared towards the exploitation of fishery resources. Even with a dedicated conservation team, such cultural impediments can not be changed quickly.

In contrast, NPWS has been established as the agency dealing with the conservation and preservation of our environment. Yet they do not have jurisdiction over aquatic areas, although they are the agency that deals with protection *in situ* of terrestrial and wetland areas. Owing to this, the NPWS lacks sufficient management tools to conserve species and habitats that occur in aquatic environments for which it has a legislative responsibility under the *Threatened Species Conservation Act 1997* (NSW) and *National Parks and Wildlife Act 1974* (NSW) (such as waterbirds, riparian zones, floodplains, freshwater plants and amphibians). This conclusion is justified by the present habitat degradation in the majority of freshwater environments, the impoverished condition of aquatic biota and the number of listed threatened aquatic species.

The Department of Land and Water Conservation also plays an important role in protecting freshwater aquatic areas. Its role as the lead agency in water and land management has major implications for species and ecosystem health, because some of the major causes of the decline of threatened species and their habitat occur *ex situ*, such as river regulation and catchment management practices.

Fisheries issues, water and catchment management issues and biodiversity conservation in freshwater aquatic systems are all interdependent, yet are dealt with through a very segregated political process. This has also led to ownership problems, both in relation to addressing environmental issues and requirements and also regarding who is responsible for meeting the numerous policy commitments that have been made by the government. Strained resources and insufficient resource allocation have also enhanced a reluctance to begin a difficult, potentially costly and politically sensitive process.

The formation of a Freshwater Aquatic Reserves Interagency Working Group is an important mechanism to overcome impediments to the establishment of a system of FARs. Not only political segregation and ownership problems, but issues such as the lack of staff and resources commitment will become less of a problem with involvement from multiple departments, particularly as NPWS is in a position for greater commitment to conservation requirements. Such departmental union is not a foreign concept, as mentioned earlier in regard to Marine Parks, where experience demonstrated that greater communication and joint management enhanced the establishment of protected areas.

The experience gained by NPWS staff in managing the large number of waterways that fall within terrestrial reserves would be invaluable in guiding the establishment of FARs in conjunction with Fisheries. Such a partnership would ensure that there is a greater link between terrestrial and aquatic conservation *in situ*, and could encourage supportive terrestrial protection for the FARs. Further, it would use the NSWF MPA experience and protection area management from NPWS. The involvement of DLWC is also critical and would assist in addressing the establishment problem posed by the very nature of rivers and the inability of a FAR to directly prevent or regulate upstream activities which adversely affect aquatic biodiversity and habitat within the FAR.

The Working Group would be in a valuable position to examine and refine options for establishing FARs, and would also be able to draft a long-overdue policy on the establishment and management of FARs. It should also undertake community consultation to raise awareness of the need for FARs, and advice should be provided through a Freshwater Aquatic Reserves Community Reference Panel to be established jointly by the NSW Minister for Fisheries and Minister for the Environment. Establishment of this panel may also assist in the development of long-term working relationships between fish conservation staff and river stakeholders; these relationships will further enhance FAR establishment.

Legislative confusion should be addressed through the amendment of the *FM Act* and *NPW Act* as appropriate to enhance the capacity of the NSW Government to establish and manage a system of FARs. Even though the legislation is adequate, such alterations would assist in the specification and clarification of each department's position for FAR establishment.

Objectives of FARs

All types of protection areas, including aquatic reserves, should be selected, declared and managed according to guidelines being developed under the Aquatic Biodiversity Strategy. The management objectives of FARs could be to:

1. develop a CAR system of reserves;
2. protect aquatic habitat and biodiversity in the reserve (FM Act, section 194(2));
3. provide for species management in the reserve, such as angling restrictions (FM Act, section 194(2));
4. protect threatened species, populations and ecological communities in the reserve (FM Act, section 194(2));
5. protect river reaches supporting species that are rare or have a limited distribution;
6. facilitate educational activities and scientific research (FM Act, section 194(2));
7. raise awareness amongst the general community regarding river health;

8. manage and conserve aquatic ecosystems in pristine condition, particularly streams classified as High Conservation Value;
9. provide NSW Fisheries with a stronger role in managing rivers and catchments, particularly in delivering environmental flows, mitigating thermal pollution from dams and providing fish passage; and
10. provide for complementary management of reserved freshwater ecosystems in association with terrestrial reserves and Ramsar-listed wetlands.

Levels of protection and management actions within a FAR

Three categories of FARs are proposed which correspond to three of the IUCN categories of Protected Areas (Environment Australia 2001). Below these suggestions are proposed management actions and conditions of access to a river and use of its resources. These categories would combine with potential management requirements that indicate the level of intervention, as well as the extent to which they include addressing *ex situ* issues. However, it is worth noting that waterways in wilderness areas or strict nature reserves may be better protected by a Category I reserve, the goal of which is to manage mainly for science or wilderness protection.

Category II: Protected area managed mainly for ecosystem conservation and recreation. This category provides the highest level of protection and it should be considered the default option for most FARs. Goal: to provide a natural area designated to

(a) protect the ecological integrity of one or more ecosystems for this and future generations;

(b) exclude exploitation or occupation inimical to the purpose of designation of the area; and

(c) provide a foundation for spiritual, scientific, educational, recreational and visitor opportunities, all of which must be environmentally and culturally compatible.

Category IV: Protected area managed mainly for conservation through management intervention. Goal: to provide an area subject to active intervention for management purposes so as to ensure the maintenance of habitats and/or to meet the requirements of specific species.

Category VI: Protected area managed mainly for the sustainable use of natural ecosystems. Goal: area containing predominantly unmodified natural systems, managed to ensure long-term protection and maintenance of biological diversity, while providing for a sustainable flow of natural products and services to meet community needs.

Protected areas will be effective only if scope is provided for an effectively sized no-take/sanctuary zone, and the Australian Committee for IUCN believes that the most effective protection is gained from the establishment of a large area managed for multiple use and including adequately sized sanctuary zones (ACIUCN 1994). The Inland Rivers Network strongly supports the use of Category II, particularly for priority areas containing, for example, critical habitat, threatened species or representative communities.

Provision for lower management requirementsdemonstrates recognition for the need for flexibility, because in some situations it may be necessary to secure freshwater reserve establishment. Alternatively, where there is little present or future threat to the health and integrity of the aquatic ecosystem, such categories may also be adequate.

The management actions and conditions broadly address the threatening processes listed in Table 1. For a Category II reserve, management options should include

- **Re-introduction of locally extinct specie**s. FARs could be used for careful re-introduction of some of the many species that have become regionally extinct throughout inland NSW..
- **No-take zones and angling restrictions.** Complete angling closures could be declared across some or all of a FAR, though for many species angling pressure is not a major concern. Alternatively, or with multi-zoning, restrictions on fishing could be increased, such as longer closed seasons or lower bag limits, particularly during the spawning season.
- **Powerboat management.** Exclusion of powerboats in critical areas is highly desirable. Wakes created by speedboats seriously degrade aquatic vegetation and the fauna that rely on plants for habitat and protection. Anecdotal evidence indicates that noisy boats also scare fish. Alternatively, access to some or all of the waterway could be restricted to boats with small engines and canoes.
- **Remove/modify weirs.** Weirs within, upstream or downstream of a FAR that block fish passage, alter flow patterns, encourage exotic species, or cause erosion and salinity could be modified or removed, or targeted for the addition of a fishway. Weir manipulations could be required to accord with the objectives of the FAR.

- **Mitigate cold-water pollution**. Bottom-release dams that thermally pollute a FAR could be targeted for mitigation.
- **Deliver environmental flows**. Improved flow management is central to the management and rehabilitation of many inland rivers, with the Fisheries Scientific Committee identifying changes to flow patterns as a key threatening process. Improved flow management upstream of a FAR could be a key management tool.
- **Control of exotic species**. Management and/or removal of introduced plant pests (willows, blackberries, burrs, *Lippia*, etc.) and animal pests (e.g. carp, redfin, trout, mosquito fish).
- **Improved management of agricultural run-off and irrigation drainage**. Tighter controls on discharge from irrigation drains that discharge into or upstream of a FAR, mandatory construction of wetlands to filter drainage discharge, and establishment of vegetation buffer strips along agricultural lands is a key river rehabilitation tool.
- **General habitat rehabilitation.** To enhance the capacity of the river to provide natural products (e.g. increased recreational fish catch of native fish species) and services (e.g. improved amenity and water quality) arising from improved river health.
- **Communication to local community of fish conservation matters**. Construction of riverbank signs, and fact sheet and occasional newsletter distribution to the community and visitors regarding management aims, and fish and habitats present in the FAR.
- **Riparian-zone protection.** Stock management and exclusion along sensitive riverbanks and wetlands/billabongs, with provision of off-creek watering where required. Management of remnant vegetation and re-vegetation.
- **Scientific research and monitoring.** Research and management programs for aquatic biodiversity and river management could focus on FARs, e.g. regarding re-snagging or the effectiveness of recovery plans. FARs declared over high-quality habitats could also fulfil the role of reference sites for the purposes of long-term monitoring programs.
- **Re-snagging and protection of snag**s. Snags are essential habitat for many fish and other aquatic fauna, but hundreds of thousands of snags have been removed from rivers in southern NSW. Re-snagging will be a key component of recovery plans for certain species (such as trout cod) and could be implemented in FARs.

Site selection

Reserve selection could usefully be based on a biogeographic regionalisation of freshwater ecosystems, as used in terrestrial reserve selection (CoAG 1996). A CAR system of FARs could be established that included representative headwater streams, constrained reaches, braided and anastomosing reaches, floodplains and wetlands/billabongs. Identification and selection criteria could be based on those developed for MPAs, and also with consideration of Ramsar criteria pertinent to fish.

The size of FARs should be determined through consideration of the reserve objectives and by taking into account factors such as the habitat requirements of the species to be protected and their dispersal requirements (Thackway 1996). FARs that are too small to adequately provide for the protection of a species or community or habitat risk being merely token gestures. The scale of threats and their impacts should also be taken into consideration, such as the extent of cold-water releases from dams or the quality of riparian vegetation.

Within the proposed biogeographic regionalisation of NSW rivers, and cognisant of the financial, practical and legal constraints pertinent to the declaration of FARs, the following river reaches should be investigated for their suitability:

- Reaches of the Paroo, Warrego, Barwon and Narran Rivers;
- The River Murray between Echuca and Yarrawonga, in consultation with the Victorian Government;
- Reaches of the upper Murrumbidgee River, in consultation with the ACT Government;
- Reaches of the lower Murrumbidgee River;
- Reaches of the upper Clarence and Richmond Rivers, which support the endangered trout cod; and
- Reaches of the upper Gwydir River, which support some healthy fish populations.

Compatibility of FARs with different land tenures

Establishment of FARs on publicly owned land will be much easier than on privately owned land, particularly as privately owned land often extends to the edge of rivers and creeks and sometimes into the channel. Particularly for publicly owned lands, such as forestry lands managed by NSW Forests, FARs could be established with a simple transfer of the lease to NSW Fisheries. An example of where this simple lease transfer could apply would be the bed of the River Murray, which is managed under lease by DLWC where it passes though the Barmah–Millewa Forest. Millewa Forest is managed for forestry by NSW Forests, with forestry operations in riparian zones strictly managed to protect waterways. Given that the Barmah Forest (Victoria) is a Ramsar-listed wetland and forestry operations in Millewa Forest provide a high level of protection to riparian and floodplain habitats along the River Murray, and the River Murray supports high fish and habitat diversity in the reach, the site warrants strong consideration for declaration of a FAR.

Voluntary conservation agreements (VCAs) involve negotiations between the landholder and NSW Minister for Environment to form a binding contract, and are provided for in the *National Parks and Wildlife Act 1974* (NSW) (Section 69). An agreement over land may be reached for various purposes, including the conservation of threatened species or their habitats (Section 69b-c). VCAs may provide an avenue for effective, flexible protection of freshwater areas that adjoin private land (NPWS 1999). Not only do they allow for the coexistence of conservation and private land use, they could enable the establishment of a freshwater reserve without the need for expensive compulsory acquisition, overcoming potentially difficult land-tenure issues. Of further incentive to landholders, recent amendments to the *Local Government Act 1993* have empowered Councils to offer rate rebates on land under a VCA, thereby making those landholders exempt (or partially exempt) from rates and charges (NPWS 1999). In most cases a FAR may need to extend only to the top of the river bank, and the imposition upon landholders of changed management practices or cost of acquiring the land may not be onerous. There is the potential for much flexibility to allow an effective compromise to be developed between the goals of a FAR and those of the landholder, particularly through the use of education, incentives and consultation.

CONCLUSION

A comprehensive, adequate and representative system of FARs needs to be established across rivers and creeks in New South Wales. Reserve selection should be based on a biogeographic regionalisation of waterways. As a matter of practicality and within the regionalisation, rivers and creeks that fall within terrestrial reserves already managed for nature conservation should be given priority for declaration as FARs.

A FAR Working Group needs to be established, jointly staffed by NSW Fisheries and the National Parks & Wildlife Service, as well as the Department of Land & Water Conservation, to examine and refine options for establishing FARs. This would include drafting a policy on establishing and managing FARs, if an establishment process and timetable for implementation was not set up by the NSW *Aquatic Biodiversity Strategy*. The Working Group should also conduct community consultation and education, should build long-term relationships with landholders, and should strongly consider using voluntary conservation agreements to overcome land-tenure issues.

Three categories of aquatic reserves are proposed in accordance with categories of protected areas endorsed by the IUCN, to indicate flexibility in FAR establishment and zonation. However, the use of category II is recommended as the most appropriate, particularly for priority areas containing, for example, critical habitat, threatened species or representative communities. There are a number of important management options that should be seriously considered for such reserves.

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REPRESENTATIVE FRESHWATER AQUATIC PROTECTED AREAS: THE AUSTRALIAN CONTEXT

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Abstract

Australian governments (at national and State levels) are committed, on paper, to the development of systems of reserves containing representative examples of all major freshwater ecosystems. We review policy and programs at both national and State levels related to these commitments. We conclude that, to the extent that such reserves have been developed, this has generally occurred incidentally rather than deliberately. Recommendations are made focused on mechanisms to facilitate implementation programs through (a) developing nationally consistent approaches to ecosystem classification and inventory, and (b) identifying gaps in existing reserve systems, and selecting possible sites to fill the gaps.

Keywords: representative, reserves, freshwater, ecosystems, protected areas

INTRODUCTION

Biodiversity needs to be protected within the landscape – it is neither practical nor effective to conserve biodiversity values within 'captive ecosystems'. Within this larger framework, protected areas (or reserves) play a crucial role. This paper summarizes the development of representative freshwater reserves in Australia.

Protected areas established to conserve representative examples of major ecosystems are an accepted component of terrestrial and marine biodiversity conservation programs. The establishment of such reserves is in fact a obligation for nations, including Australia, that have signed the International Convention on Biological Diversity 1992. Additionally, representative reserves have important value in protecting ecosystems of special importance, and in providing ecologically-based benchmarks useful in assessing the sustainability of management programs. At a national level, the establishment of representative freshwater reserves is an explicit requirement of the Council of Australian Government's 1992 Inter-Governmental Agreement on the Environment.

However, in spite of these international and national commitments, Australian State governments have been slow to establish systems of representative reserves in freshwater environments. Although all eight Australian jurisdictions have endorsed the concept of such reserves in policy statements, only Victoria, the Australian Capital Territory and Tasmania have developed programs to implement these commitments. In two of these three jurisdictions the programs remain incomplete. Existing terrestrial reserves do protect some important examples of representative freshwater ecosystems, but there appear to be many important gaps – especially relating to river and aquifer ecosystems.

THE NATIONAL CONTEXT

The establishment of networks of freshwater protected areas (PAs) including representative reserves has been identified as a commitment of all Australian governments in several key strategies, including the National Strategy for Ecologically Sustainable Development (Commonwealth of Australia 1992a), the Inter-Governmental Agreement on the Environment (Commonwealth of Australia 1992b) and the National Strategy for the Conservation of Australia's Biological Diversity (Commonwealth of Australia 1996).

Objective 10.1 of the National Strategy for Ecologically Sustainable Development states that the objective for a nature conservation system is:

> *To establish across the nation a comprehensive system of protected areas which includes representative samples of all major ecosystems, both terrestrial and aquatic; manage the overall impacts of human use on protected areas; and restore habitats and ameliorate existing impacts such that nature conservation values are maintained and enhanced.* (Commonwealth of Australia 1992a; p. 54)

Item 13 of the Inter-Governmental Agreement on the Environment schedule on Nature Conservation states that:

> *The parties agree that a representative system of protected areas encompassing terrestrial, freshwater, estuarine and marine environments is a significant component in maintaining ecological processes and systems. It also provides a valuable basis for environmental education and environmental monitoring. Such a system will be enhanced by the development and application where appropriate of nationally consistent principles for management of reserves.* (Commonwealth of Australia 1992b; p. 40)

In the National Strategy for the Conservation of Australia's Biological Diversity, protected areas are to be integrated with other measures for achieving ecologically sustainable use of natural resources. Objective 1.4 states:

> *Establish and manage a comprehensive, adequate and representative system of protected areas covering Australia's biodiversity* (Commonwealth of Australia 1996; p. 9).

It is generally recognised that a system of protected areas needs to be representative of ecosystem biodiversity. Without systems of representative reserves, biodiversity will decline as ecosystems are modified and simplified by human use.

In spite of the commitments set out above, there is at present no national program specifically to assist the States in developing systems of representative freshwater reserves. The National Reserves System (NRS) does protect many wetland ecosystems, but no attempt has been made at this stage to assess their representative characteristics. Whereas some wetland types will be well protected with the NRS framework, others will not. At this stage we do not know the situation regarding the conservation status of freshwater ecosystems, because no State has a comprehensive inventory on which to base an assessment. It seems safe to speculate, however, that the NRS does not do a great deal to protect representative rivers and aquifer ecosystems, except in instances where these ecosystems form comparatively small components in large terrestrial reserves.

National Ramsar commitments and programs include the development of inventories and the establishment of protected areas. However, such programs remain incomplete in all Australian jurisdictions except the Australian Capital Territory.

According to the minutes of the Land, Water and Biodiversity Committee of the Natural Resources Management Ministerial Council (NRMMC) Meeting 1, December 2001, the Council has considered establishing an inter-jurisdictional working group to explore the feasibility of creating a national reserves system for 'Inland Aquatic Ecosystems'. It is understood that the setting-up of this group will be further considered following the completion of a Directions Statement on the NRS (this document is known as the NRS Action Plan.)

Given the commitments that have already been made (see below), one would think that such a working group might be more effective if, rather than examining the issue of *feasibility*, it was asked to examine the *implementation* of existing commitments regarding the protection of freshwater ecosystems within the framework provided by the NRS and State NRM programs.

Terminology

Where the term "*freshwater ecosystem*" is used, this includes all habitats covered by the Ramsar definition of the term "wetland", including river, aquifer, ephemeral wetland, and estuarine ecosystems (where such ecosystem is heavily dependent on freshwater flows. Where the tem "*wetland*" is used (unless it is specifically mentioned that the Ramsar definition is being used in that context), the term equates to the definition used in the Commonwealth Wetlands Policy (see Appendix 8 of the Australian Society for Limnology discussion paper on representative reserves).

AUSTRALIAN CAPITAL TERRITORY (ACT)

The ACT, being Australia's smallest jurisdiction (by a long way) is also in the position where all land is either Crown controlled, or leased from the Crown. Given this unusual situation and a single State/Local Government administration, land management presents arguably less complex challenges here than in other jurisdictions.

The ACT Nature Conservation Strategy (NCS) 1998 takes the place of both a biodiversity strategy and a wetlands strategy. The NCS does not include specific commitments to the development of representative freshwater reserves; however, it does make clear commitments to establish comprehensive, adequate and representative (CAR) protection of *all* ecosystems, and states: "riverine systems are … an area of concern".

This commitment has already been largely completed, owing to the small size of the ACT. The Cotter and Murrumbidgee are the two rivers of highest ecological value. The Murrumbidgee is largely protected in the series of reserves that form the Murrumbidgee River Corridor, and the Molonglo River below Coppins Crossing is similarly protected. The great majority of the

Cotter River is protected within Namadgi National Park (B Wilkinson, *pers. comm.*)

The NCS makes commitments: to complete the ecological survey of the ACT, and to identify deficiencies and gaps in the reserve system. This program should lead, in theory, to:

- the development of a comprehensive freshwater inventory, although this is not identified as an outcome; and
- the development of a system of representative reserves which includes examples of all major aquatic ecosystems.

Action plans for threatened species and ecological communities prepared under the Nature Conservation Act 1980 are reviewed every 3 years and updated as necessary. CAR reserves (all ecosystems) are being reviewed and developed within an Interim Biogeographic Regionalisation of Australia (IBRA) framework.

NEW SOUTH WALES (NSW)

NSW has three key strategies[1] affecting freshwater biodiversity, all fitting within the general framework created by the NSW *Catchment Management Act 1989*, the *Water Management Act 2000*, the *Fisheries Management Act 1994*, and the NSW Total Catchment Management Policy 1987. These are:

- the Rivers and Estuaries Policy 1993.
- the Wetlands Management Policy 1996, and
- the Biodiversity Strategy 1999.

All three strategies contain clear commitments to the establishment of representative freshwater protected areas. However, the NSW government has not allocated specific funds to any program focused on putting such a network of freshwater PAs in place. Although Objective 2.2 of the Biodiversity Strategy is to 'establish a comprehensive, adequate and representative reserve system', the Strategy defers issues in the freshwater area by stating:

> NSW Fisheries is preparing an additional component to the Biodiversity Strategy, dealing with the protection of … the fish and other organisms in our streams, rivers and lakes. A draft will be released for public comment in late 1999.

This draft had not been released at the time of publication of these proceedings.

Aquatic reserves may be declared under the *Fisheries Management Act* (managed by NSW Fisheries). There are thirteen aquatic reserves in NSW, spanning some 2100 ha – but none as yet in fresh water. These reserves have generally been declared to protect small areas of habitat vulnerable to damage from high usage (tidal rock platforms, for example). Although such reserves could be declared over freshwater areas, all existing areas protect marine or estuarine locations.

The NSW State of the Environment Report 2001 reviewed the matter of freshwater reserves, and recommended (p.263) that existing management programs '… would be complemented by the development of a protected area system for riverine habitats'. The draft *State Water Management Outcomes Plan 2002* contains a target to establish aquatic reference sites based on biogeographical regions. The purpose of the sites is "to provide benchmarks for habitats and ecological flow response assessment". If implemented, this target could provide a framework for establishing representative freshwater protected areas in each bioregion within NSW, although 'reference sites' could alternatively be interpreted in a more restrictive way simply as monitoring sites in unprotected areas.

NORTHERN TERRITORY (NT)

The National Parks and Wildlife Commission of the Northern Territory has produced two strategies: the first (1999) dealing with threatened species and communities[2], the second (2000) dealing with wetlands. The NT has no plans to develop a Biodiversity Strategy.

Both of the NT's strategies follow similar formats: a goal and guiding principles lead to objectives, and action statements address the objectives. Both strategies acknowledge international and national biodiversity protection frameworks. For the purposes of policy implementation, the NT government regards the NT wetlands strategy as including rivers and streams (M Butler, *pers. comm.*).

The wetlands strategy contains a commitment to the establishment of *representative* wetland reserves:

Objective five:

To enhance the system of National Parks and other protected areas to maintain the full range of wetland types and ecological functions.

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[1] The groundwater policies (framework, quality, flow, and groundwater-dependent ecosystems), and the Weirs Policy (1997) are important supporting policies to this group.

[2] Government of the Northern Territory (1999).

Action statements include the following:

- identify wetlands in each biogeographic region of the Northern Territory;
- undertake biological and environmental surveys of wetlands;
- develop a wetland inventory based on geographical information system (GIS); and
- examine the range of wetland types included in the present reserve system, and identify gaps in representation.

This framework provides a good basis on which to develop CAR wetland reserves, and could easily be expanded by a minor policy statement to include riverine as well as the more traditional "still water" wetlands, because the Northern Territory administration includes 'rivers' under its definition of wetland. This places the NT in much the same position as most other Australian jurisdictions: the commitments have been made, but not yet implemented.

QUEENSLAND

Queensland's key strategy in this area is the *Wetlands Strategy 1999*. The Ramsar definition of wetlands (in a slightly modified form) is used, covering *static or flowing* waters.

The Strategy has four central objectives, of which Objectives 2 and 3 are particularly important:

- 2. Ensure a comprehensive and adequate representation of wetlands in the conservation reserve system;
- 3. Base the management and use of natural wetlands on ecologically sustainable management and integrated catchment management practices.

The Strategy commits the Queensland government to the development of representative freshwater reserves through Objective 2. Disappointingly, however, initiatives 1.1, 1.3 & 1.5 do not identify the need for a comprehensive State inventory of wetlands which would lay the foundations for the development of CAR freshwater reserves, and initiative 2.1 merely re-states the objective. It seems possible that the development of a *Queensland Rivers Policy* could see these gaps covered – although this initiative, alive in 2001, seems now dormant.

Under the Queensland government's wetlands program, considerable progress has been made in assembling inventory material over the past three decades. Although the Wetlands Inventory program includes rivers, the limited data collected do not appear to have been used in a systematic way to help identify rivers of high conservation value.

Fish Habitat Areas can be declared under the provisions of Queensland's *Fisheries Act 1994*. Although around 10,000 km^2 of estuarine habitat is protected under these provisions, they have not yet been applied to significant freshwater areas.

SOUTH AUSTRALIA (SA)

The draft Wetlands Strategy for South Australia (2002) provides a mandate for the development of both a comprehensive wetland inventory and reserves protecting comprehensive, adequate and representative examples of wetland types.

> **Objective 5.** To identify those wetlands which are important at the regional, state, national and international levels, and ensure appropriate recognition, management and protection of these sites.
>
> **Actions:**
>
> 5.1 Establish a comprehensive, adequate and representative system of protected areas to contribute to the conservation of South Australia's native biodiversity associated with wetlands.
>
> 5.2 Ensure that key wetland sites are identified in the State Wetlands Databank (see Action 6.1) defining their importance at the regional, state, national and international levels. Collate monitoring, survey, and management information for wetlands across the state and link these data to information from associated water resources that wetlands rely upon.

South Australia has a wetlands inventory program, where inventories are being developed region by region with the intention of achieving full State coverage; this program is being developed within a limited budget. There are no plans at present to establish a comprehensive inventory of freshwater ecosystems, including both flowing and still waters. The State is however, progressing the development of a broad-scale inventory of terrestrial ecosystems, within the IBRA framework, and this may ultimately be extended to cover freshwater ecosystems, particularly given the use of the Ramsar definition of wetlands within the State wetlands strategy.

The State has no threatened species legislation. Prior to the publication of the wetlands strategy, there were no requirements for local government, within the State's landuse planning framework, to take biodiversity or wetlands inventories into account when considering development proposals or changes to landuse zoning. This has changed under Objective 5 of the strategy.

South Australia has followed all other jurisdictions in committing to comprehensive, adequate and representative freshwater protected areas. The critical issue now is funding programs to develop comprehensive freshwater ecosystem inventories, and identify and rectify gaps in the existing reserve system.

TASMANIA

The final version of Tasmania's Nature Conservation Strategy 2002-2006 contained a 'priority recommendation' (p.ii):

> Improve protection for freshwater environments. As a priority, identify and establish freshwater CAR reserves and complete integrated catchment planning for natural resource management. (Expanded by Actions 15, 47)

The Conservation of Freshwater Ecosystem Values (CFEV) Project has been initiated by the Tasmanian Government as part of the Water Development Plan for Tasmania. The Department of Primary Industries, Water and Environment (DPIWE) is responsible for the Plan. The development and implementation of a strategic framework for the management and conservation of the State's streams, waterways, and wetlands is identified as an integral part of the Water Development Plan.

The project will consider in its scope the following ecosystem types: *rivers, lakes and wetlands, saltmarshes, estuaries,* and *groundwater dependent ecosystems*.

The project aims to develop a Freshwater Conservation System for Tasmania, based on the reserve-design principles of comprehensive, adequate and representative protection (CAR Principles), in order to achieve the following outcomes:

- a coordinated system for the recognition and conservation of freshwater ecosystem values that can be used for water management planning;
- increased conservation of high priority freshwater ecosystem values in areas under both Crown control and private land;
- increased confidence on behalf of government, industry and the community that high priority freshwater ecosystem values are appropriately considered in the development and management of the State's water resources; and
- increased ability for Tasmania to meet national obligations for protection of freshwater ecosystems.

A comprehensive inventory of Tasmania's freshwater ecosystems is under development as an adjunct to this project. Tasmania's wetland inventory has been expanded from around 1000 sites in 1999 to currently contain information on 8000 sites. See Appendix 10 in Nevill and Phillips (2003) for more information on the CFEV project.

Tasmania's Inland Fisheries Act 1995 contains provisions for establishing fauna reserves. As yet, these provisions have not been used.

VICTORIA

Victoria has been, and remains, a leader with regard to the protection of representative examples of freshwater ecosystems, in spite of failings in the implementation of policy. The *Reference Areas Act 1978* was, at the time, benchmark legislation with regard to the protection of representative terrestrial ecosystems. The *State Conservation Strategy 1987* established the need for representative protected areas covering both rivers and wetlands. The recommendations of the Land Conservation Council (LCC) *Rivers and Streams Investigation* in 1991 resulted in the designation of 15 *representative rivers*, and the development of protective management plans for 11 of these. The LCC's recommendations also resulted in the passage of the *Heritage Rivers Act 1992*, which provided statutory protection to 18 river reaches and 26 small but relatively undisturbed catchments of high natural value.

The *Heritage Rivers Act* represents benchmark river protection legislation in the Australian context. Although attempts have been made by other Australian jurisdictions to develop similar legislation, all have failed. *Victoria's Biodiversity*, released in 1997, re-iterated earlier commitments towards representative reserves covering both wetlands and rivers. The *Victorian Healthy Rivers Strategy* 2002 identifies the need for representative river ecosystems, and included the development of a strategic target.

This record surpasses that of any other Australian State. However, Victoria failed to carry through aspects of the *State Conservation Strategy 1987* and the 1997 biodiversity strategy which would have seen the development of a comprehensive and representative protected area network covering wetlands. In addition, although the Victorian government instructed its departments to implement protective management for the designated *representative rivers* in 1992, after 10 years four of those 15 rivers remain without management plans. The implementation of the 11 plans that have been prepared has not been publicly reported.

The Victorian Government, through the Victorian River Health Strategy (VRHS) (launched August 2002) is committed to review representative rivers in view of their ecological attributes. This review will apparently be undertaken by the Victorian Environment Assessment Council (VEAC) (the successor to the LCC), with relevant Catchment Management Authorities required to prepare management plans for the rivers. The VRHS strategic target is that identified representative river reaches should be ecologically healthy by 2021. It is hoped that these arrangements will lead to a more detailed and comprehensive system for identifying and managing representative rivers in Victoria.

The VEAC is the logical vehicle to resuscitate earlier (1987) plans by the LCC to examine the issue of representative wetlands. The Victorian Government is understood to be considering this option.

WESTERN AUSTRALIA

The Western Australian Government published a *Wetlands Conservation Policy* in 1997, divided into two main sections, a *Statement of Policy* and a second section on *Policy Implementation.* The Statement of Policy *uses the full Ramsar definition of wetlands*, and thus applies to virtually all Western Australian freshwater ecosystems – rivers, lakes, floodplain wetlands, estuaries, and underground karst environments. Given that State wetland policies are in part designed to facilitate the fulfilment of Australia's international commitments under the Ramsar Convention, this approach appears logical and courageous, and one that other Australian States could do well to follow.

Moreover, the Policy provides a commitment that should provide the foundations for the development of a system of comprehensive, adequate and representative freshwater ecosystem reserves. *Objective 2* commits the State Government to the protection of "viable representatives of all major wetland types" – again, using the full Ramsar definition of wetlands. However, the policy implementation plans – the second part of the Policy – are limited to "still" waters only. The logic for this division provides for the values of 'flowing' water wetlands (i.e. rivers) to be protected under the programs developed by the then WA *Water and Rivers Commission*.

At this stage WA does not have a biodiversity strategy. Draft versions of *A Nature Conservation Strategy for Western Australia* and a Wildlife Conservation Bill to replace the WA *Wildlife Conservation Act 1950* were released for public comment in 1992. Since then, successive State governments have committed to develop a Biodiversity Conservation Strategy and, similarly, to comprehensive biodiversity conservation legislation to replace the Wildlife Conservation Act[3]. Work towards these initiatives continues.

Comprehensive strategic inventories of the State's freshwater ecosystems, and the procedures necessary to support effective integration of land-use planning and environmental-assessment procedures, are in early stages of development. Under the *Wetlands Conservation Policy*, catchment-based inventories of "still" wetlands are being prepared by the Department of Conservation and Land Management. The scope and coverage of these inventories vary from catchment to catchment – an appropriate early response in such a large State where threats and pressures vary significantly with distance from the main population centres.

WA also has an Environmental Protection Policy for the Swan Coastal Plain Wetlands, which aims to protect the 20% of remaining conservation-category wetlands from the effects of land development.

A draft Statement of Planning Policy for Natural Resource Management has been released for public comment. This initiative aims to provide the mechanisms for natural resource management issues to be embedded into local government planning schemes and thus development decisions. The draft SPP includes a sub-component dealing with wetlands.

The WA government released the *Draft Waterways WA Policy* in November 2000 for comment. In many ways a progressive document, the draft failed[4] to pick up and expand the existing policy statements relevant to waterways set by the Wetlands Conservation Policy 1997. In this respect, the most important missing element relates to the development of representative freshwater reserves. The final version of this policy has not been released[5], because the government hoped to develop a draft waterways strategy (which is likely to include a commitment to protect near-pristine rivers of high conservation value) and release both the policy and strategy together in early 2003. A check of the WA Government website suggested that neither document had been released at the time of these proceedings .

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[3] CALM website checked 14/6/02.

[4] For more detail, see http://www.netspace.net.au/~jnevill/Submission_WA_waterways.doc .

[5] WRC website checked 14/6/02 – draft policy 2000 still listed as available. No information on final policy availability.

AUSTRALIAN INVENTORIES OF FRESHWATER ECOSYSTEMS

Generally speaking, all jurisdictions have developed State-wide inventories for *important wetlands*, although in every case except the ACT these inventories remain under development or review. Only the ACT, NSW and Victoria have developed detailed *river* inventories, although all other jurisdictions have initiated river inventory projects of some kind. The national wild rivers database was constructed from information supplied by State governments. *Subterranean ecosystems* (aquifers) have not been inventoried in any jurisdiction, although NSW has made plans to initiate inventory projects, subject to funding.

The condition of State inventories of freshwater ecosystems can be assessed by the use of four criteria.

- Are they *comprehensive*? – do they cover rivers and subterranean ecosystems as well as wetlands?
- Do they contain adequate information on ecosystem *values* to support State planning and assessment frameworks?
- Do they contain *condition* indices enabling ongoing reporting? Sustainability targets depend on these data – without them the effectiveness of 'sustainable' resource management cannot be adequately assessed.
- Are they readily *accessible*, not only to decision-makers, but to all relevant stakeholders?

Natural Heritage Trust funding, as well as funding through State river health programs and the Commonwealth Land and Water Australia / Environment Australia river health programs, has enabled considerable information on condition to be collected by the use of AusRivAS macroinvertebrate data and condition indices such as the Victorian Index of Stream Condition. The National Water Quality Management Strategy (formally backed by the Council of Australian Governments COAG water reform framework, and more recently the National Action Plan) has provided a nationally consistent framework for the collection and evaluation of water quality data.

At this stage, information on the fine details of State inventory programs has proved difficult to obtain. It seems safe to say, however, that inventories of wetlands are better developed than inventories of river or subterranean ecosystems. Inventory data on value are sparse in several States, but generally more available than data on condition. Public accessibility to inventory data varies considerably depending on the type and scale of the data, but is difficult in several jurisdictions. Some data held by State agencies (like the Queensland river value data, for example) have not been released at this stage – so are effectively completely inaccessible.

Victoria, New South Wales, Queensland and Tasmania all have State-wide wetland inventories, although in all cases except Victoria these inventories are incomplete even with respect to location data for smaller wetland types. None of these inventories contains comprehensive value or condition information. Victoria, New South Wales and Queensland have funded projects specifically aimed at identifying rivers of high natural value. At this stage, the report from the Queensland program remains unpublished, whereas both Victoria and NSW have published reports.

Only Victoria has a State-wide inventory of river ecosystems carrying data on value and condition – however, even here data access is a problem, because information is contained in a variety of datasets, some of which are difficult to obtain or out-of-date. No jurisdiction has developed a State-wide inventory of subterranean ecosystems, and New South Wales is the only jurisdiction to propose the development of such an inventory.

Inventory recommendations

All States need to take major steps to improve inventories in the interests of the sustainable management of natural values. The federal government needs to provide additional focussed funding, particularly where opportunities exist to assist efforts to develop coordinated national approaches to inventory preparation and dissemination.

Consistency of approach across different States is an area where considerable improvements could be made – for example in relation to classification systems for wetlands, rivers and aquifers. In this regard, the wetland classification methods adopted in the Queensland Wetlands Inventory may offer a useful lead.

Condition indices are another example. The Victorian Index of Stream Condition (ISC) has become widely used, and has prompted developments that may see a national approach to the measurement of stream condition. Having succeeded with rivers, research now needs to be put into developing indices applicable to different types of wetland and subterranean ecosystems. Public access to inventory data is an area where all jurisdictions need to make significant improvements.

CONCLUSION

Although all Australian jurisdictions are committed (on paper) to the development of representative freshwater reserves, only Victoria, the ACT and Tasmania have funded programs aimed specifically at these commitments. The ACT is the only jurisdiction to have fully implemented the commitment. Programs in other States that protect representative freshwater ecosystems do so more by accident than by design.

Representative freshwater protected area programs currently developing around Australia's jurisdictions are hampered by a lack of consistent approaches to ecosystem classification and inventory. Federal coordination, through the Natural Resource Management Ministerial Council, could greatly assist these programs. The most effective roles for the Australian government and the Council to take in this matter appear to be

(a) assisting the development of consistent national approaches to the classification and inventory of freshwater ecosystems, and *(b)* providing focused funding to assist in the identification and selection of representative freshwater reserves.

REFERENCES

This paper is based on a detailed analysis of State and Territory policies and programs – to be found in:

Nevill J, and Phillips N (eds)(2003) Protected Areas for Managing Rivers, Wetlands and Aquifers: the policy background, role and importance of protected areas for Australian inland aquatic ecosystems. Australian Society for Limnology Representative Reserves Working Group; Hampton Melbourne. Available from www.onlyoneplanet.com.au .

For additional references refer to http:// www. net space.net.au/~jnevill/ASL_bibliography.htm, and onlyoneplanet.com.au.

THE PRACTICALITY AND FEASIBILITY OF ESTABLISHING A SYSTEM OF FRESHWATER PROTECTED AREAS IN THE MURRAY–DARLING BASIN

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Abstract

The Murray–Darling Basin Commission is an intergovernmental commission providing advice on the planning, development and management of the Basin's resources. The Commission has prepared the Native Fish Strategy (NFS) as one of its primary responsibilities. One of the aims of this strategy is to redress the imbalance between the needs of native fish and other legitimate demands on water resources.

The NFS has two pervasive themes: to establish demonstration reaches that convey to communities the positive benefits of rehabilitation efforts and a comprehensive and adequate system of freshwater protected areas. Demonstration "rehabilitation" sites on priority river reaches are important tools to engage community support, ownership and involvement. There is a degree of public scepticism towards "locking up" parts of inland river systems as reserves. However, a demonstration reach that still provides for "wise use" as defined under IUCN categories for protected areas, and Ramsar criteria, could be the driver for declaration as a protected area. If the community can see the cumulative benefits of a number of concurrent rehabilitation efforts, such as the provision of fish passage, re-snagging, alien fish species management and environmental flows, then it may be more likely to embrace the notion of a riverine "protected area" that is better equipped to cope with the inevitable demands of upstream and downstream use. This hypothesis is applied to a case study in the form of a reach of the Ovens River that lies within the Murray–Darling Basin. Community attitudes, legislative requirements, political realities and resources are considered in discussing the feasibility and practicality of using demonstration reaches to promote the declaration of a protected area.

Keywords: demonstration reach, fish, protected area, Murray-Darling Basin

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INTRODUCTION

One of the largest catchments in the world, the Murray–Darling Basin covers one-seventh of Australia and stretches across five States and Territories. Shaped by climatic extremes and long periods of geographical isolation and geologic inactivity, Australia, and the Basin itself, possess a unique biotic assemblage that displays high endemism (Unmack 1999). However, with agricultural produce exceeding an estimated $A10 billion per year (MDBC 2002), the Basin's natural resources are under significant pressures. The loss of biodiversity in the region and degradation of its rivers is well documented. In particular, the native fish species of the Murray–Darling Basin have suffered serious declines in both distribution and abundance resulting in the threatened status of one-quarter of the thirty-five species present (MDBC 2002).

A recent snapshot of the condition of the Murray–Darling Basin classed 95% of the river length as 'degraded', with 30% modified substantially from the original condition (Norris *et al.* 2001). In addition, 40% of the river length assessed had significantly impaired biota.

The failure to catch Murray cod (*Maccullochella peeli*) at randomly selected sampling sites in a recent survey of rivers of a large portion of the Basin demonstrates the extremely patchy nature of this once ubiquitous and widespread species (although it is still found in the river**)** (Schiller *et al.* 1997). This Schiller study also recorded a decline in fish species richness with increasing distance downstream in the Murray–Darling system (Gehrke 1997), a worrying trend given that richness generally increases in this manner.

Many rivers within the Basin are threatened by multiple factors, with those of the mid and lower slopes most affected (Gippel *et al.* 2001). Blame for degraded fish populations in these rivers has been levelled mainly at human disturbances such as changes to flow regimes, alien fish species, barriers to fish migration, loss of habitat, declining water quality and overfishing (Table 1) (Kearney *et al.* 1999; MDBC 2002). These factors are not unique to Australia. They have been identified as the main threats to freshwater fish communities worldwide (Maitland 1995).

Table 1. Threats to native fish in the Murray–Darling Basin (NFS)

Threat	Threatening process
Flow regulation	Loss of water to other uses, critical low flows, loss of flow variation, loss of flow seasonality
Habitat degradation	Destruction of riparian zones, removal of in-stream habitats, sedimentation
Lowered water quality	Artificial changes in water temperature, increased nutrients, increased turbidity, salinity, pesticides, and other contaminants
Barriers	Impediments to fish passage caused by dams, weirs, culverts, etc., and non-physical barriers such as increased velocities, reduced habitats, water quality and temperature
Introduced species	Predation by and/or competition from trout, redfin, gambusia, carp, weatherloach
Exploitation	Commercial and recreational fishing pressure on depleted stocks and illegal fishing
Translocations/stockings	The loss of genetic integrity and fitness caused by inappropriate translocation and stocking of native species
Diseases	Outbreak and spread of EHNV and other viruses, diseases and parasites

Aquatic areas are also extremely important to the indigenous peoples of the Murray–Darling Basin, in terms of spiritual connection and provision of resources.

The Murray–Darling Basin Commission (MDBC) is an intergovernmental commission that provides advice on the planning, development and management of the Basin's resources. The Commission has prepared a Native Fish Strategy 2003–2013 to initiate a long-term rehabilitation program addressing the needs of native fish communities within the Murray–Darling Basin. In particular, the Strategy lists actions for rehabilitation of native fish populations and also provides direction for investment in on-ground management activities and associated research (MDBC 2002).

A recurring theme in the Strategy is the need for a comprehensive, adequate and representative system of aquatic reserves for the conservation of fish, their life cycles and habitat. The emphasis on biodiversity conservation in Australia has traditionally focussed on terrestrial and to a lesser degree marine systems. This is a gap in the biodiversity protection process that has been acknowledged by many authors both in Australia (Dunn 2000; Nevill 2001; Nevill and Phillips 2001; Hankinson and Blanch 2002) and globally (Allan and Flecker 1993; Keith 2000).

THE NEED FOR A SYSTEM OF FRESHWATER PROTECTED AREAS

Australia is an arid continent with a relative scarcity of rivers. This places its aquatic ecosystems under severe stress from the conflicting values of biodiversity conservation and the supply of natural resources, as well as emphasising their importance for protection.

Increasing awareness of the loss of Australia's biodiversity has seen the introduction of federal legislation and strategic tools aimed at the conservation and protection of this valuable, but poorly understood commodity. The Inter-Governmental Agreement on the Environment in 1992 highlighted the need for protected areas in freshwater environments as well as terrestrial and marine environments. The 1996 National Strategy for the Conservation of Australia's Biological Diversity (NSCABD) calls for the establishment of a *comprehensive*, *adequate* and *representative* (CAR) system of protected areas encompassing Australia's biodiversity. The recently finalised National Reserve System Program (NRSP) was established in 1996 to fulfil this requirement in terms of terrestrial ecosystems, and the National Representative System of Marine Protected Areas (NRSMPA) was established to protect marine ecosystems.

Although it is acknowledged that terrestrial reserves such as National Parks provide some protection to rivers and wetlands within them, management emphasis is centred on terrestrial values, giving aquatic biodiversity low priority (Keith 2000). Also, many protected areas are in the upland areas of the Basin, and as a result the middle and lowland river sections, which are the most degraded and threatened, are usually left unprotected. The concentration of terrestrial reserves in upland areas also unwittingly 'protects' a naturally relatively depauperate fish fauna, dominated by the introduced salmonids. The situation is mirrored in France, with the concentration of national parks in mountainous areas protecting salmonoid-dominated rivers of low species richness (Keith 2000). Also, the Interim Biogeographic Regionalisation for Australia (IBRA), a framework developed to identify priority regions for conservation, is not a satisfactory system for ensuring aquatic biodiversity. It does not adequately address the fine-scale variation of aquatic ecosystems when compared to the terrestrial systems for which it was devised (Nevill 2001).

As acknowledged by Nevill (2001), though most States and Territories have policy commitments in place regarding establishment of a system of freshwater aquatic reserves, only Victoria, under the Heritage Rivers Act 1992, and the Australian Capital Territory, with the Murrumbidgee River Corridor, have taken steps toward implementation. The establishment of a system of freshwater aquatic reserves or protected areas in the Murray–Darling Basin would further demonstrate Australia's commitment to biodiversity conservation and international obligations under the Convention on Biological Diversity 1992. As well, its establishment would facilitate the conservation of Australia's freshwater fish, which are of great scientific, recreational, intrinsic and economic value. Hankinson and Blanch (2002) highlight the importance of freshwater aquatic reserves as tools for the recovery of threatened aquatic species and communities, as well as for the protection of aquatic habitat.

Protected areas could also serve as 'banks' of organisms for the replenishment of unprotected or degraded areas, because the reserves provide refuge and allow population increases (Nevill and Phillips 2001). In addition, the protection of relatively unaltered lowland river reaches would create benchmarks that could be used to guide rehabilitation works in degraded reaches. Benchmarks provide not only a reference against which the effect of management in impaired systems can be compared, but also an assessment of sites for declaration as reserves (Nevill and Phillips 2001).

The adoption of a mechanism for establishing a comprehensive, adequate and representative system of freshwater reserves, similar to the NRSP and NRSMPA, where areas of high natural value gain priority in the site-identification process, may, however, exclude many ecosystem 'types', particularly wetlands and lowland rivers; this applies to lowland rivers because their general degraded nature may exclude them from selection criteria used for reserve-site selection (Table 2), and dependence is placed on them for natural resources (e.g. water extraction, and recreational and commercial angling). A mechanism is needed for rehabilitating habitat and faunal communities in lowland river reaches and wetlands, or any other degraded aquatic system, while at the same time demonstrating the benefits of healthier ecosystems to the community and stakeholders.

Identification and selection of sites for protection

Management categories for freshwater protected areas should be hierarchical and be cognisant of IUCN guidelines (IUCN 1994), ranging from sites managed for long-term maintenance of biodiversity and sustained flow of resources, to those managed for the conservation of largely intact, rare or delicate habitat. Levels of human use may decrease with increasing levels of protection, pending investigation into the impacts of a given activity on the system. Adoption of this mechanism would facilitate 'wise use' of freshwater ecosystems as defined under the "Ramsar" Convention on Wetlands, while recognising and protecting areas according to their status or significance.

Table 2. Possible criteria for freshwater protected area site selection.

Priority	Criteria
High	Species / population / community conservation status Habitat status Is the freshwater ecosystem type at this site already protected elsewhere? Rarity / irreplaceability / uniqueness of system and biota Practicality / feasibility of establishment Species diversity or richness Provides important linkage between adjacent, high quality river reaches?
High to medium	Extent of threatening processes
Medium	Existence of supportive legislation Naturalness (entire site) Scientific, educational, recreational importance of site Scientific, educational, recreational importance of fishes Economic costs / benefits of protection Availability of resources (i.e. compliance, etc.)
Medium to low	Visibility / profile / community support for proposed site
Low	Protection of genetic integrity Replication

THE DEMONSTRATION REACH CONCEPT

A lack of awareness and understanding of the biotic community and the threats facing it could be viewed as a major obstacle to the use of community support as a driver to the declaration of areas for conservation. This, coupled with the relative 'invisibility' of aquatic ecosystems when compared with terrestrial areas, necessitates a method of increasing community awareness of freshwater conservation issues and fostering support for their rehabilitation and protection.

As suggested by Nevill and Phillips (2001), the protection of biodiversity relies on two platforms: the protection of representative ecosystems via 'special areas' such as the proposed aquatic reserves; and the implementation of biodiversity-protection programs such as re-snagging and provision of fish passage. In order to meet its objective of ensuring stakeholder and community support for the Native Fish Strategy 2003-2013, the MDBC included an action for the identification of large, prominent river reaches requiring comprehensive rehabilitation to act as demonstration reaches (MDBC 2003). Successful fish conservation in the long term relies on rehabilitation of habitat and protection (Maitland 1995). Demonstration reaches are prominent and substantial river reaches requiring comprehensive rehabilitation (see Table 3). They are designed to showcase to the community the cumulative benefits of applying a number of interventions (e.g. provision for fish passage, re-snagging, alien species management) for rehabilitation of native fish habitat and populations (Fig. 1).

Table 3. Possible criteria for identification and selection of demonstration reaches

Potential demonstration reaches should:
be degraded but allow demonstration of results from rehabilitation actions;
allow trial of rehabilitation techniques and approaches;
give examples of solutions to problems;
have the ability to transfer solutions to other sites;
have wider-scale applications;
have the ability to address several threats or ecological issues;
allow the testing of scientific hypotheses and the measurement and monitoring of results;
demonstrate visibility, profile and access to the public;
demonstrate community support for rehabilitation; and
possess a potential for adequate species diversity or richness.

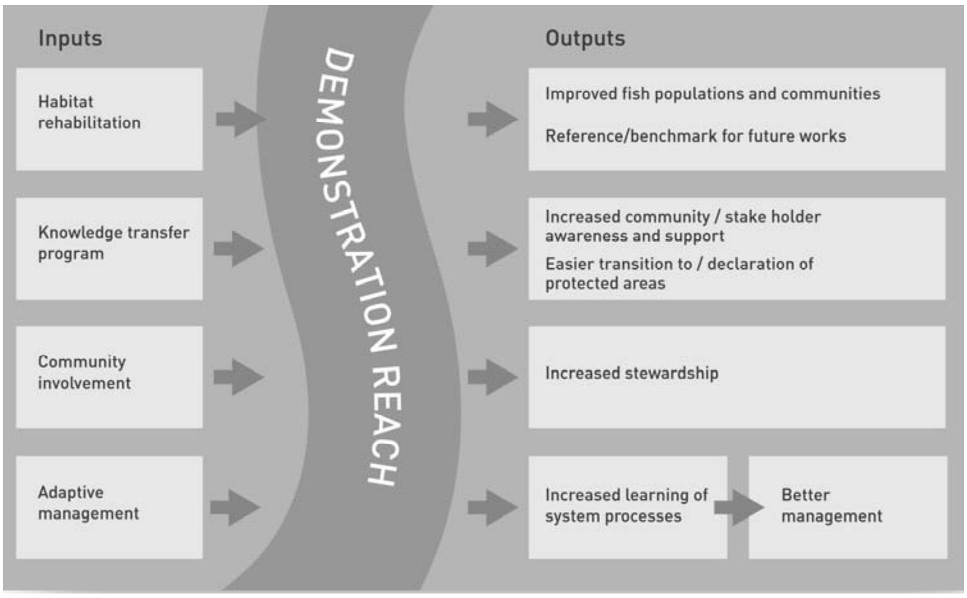

Fig. 1. The demonstration reach concept showing inputs and expected outputs.

In each demonstration reach, a program would be needed to restore values of key habitat. Management activities may include re-snagging, mitigation or removal of fish barriers, rehabilitation of the riparian zone and alien species management as well as improving water quality and environmental flows. The draft NFS has set a target of establishing and rehabilitating one demonstration reach in each of the Basin's jurisdictions to ecological functionality and sustainability by 2010. Criteria for identification and selection of Freshwater Protected Areas (FPAs) would most likely preclude lowland river reaches from selection, given their largely degraded nature, and thus the system of reserves would lack 'representativeness'. This concept of a demonstration reach addresses not only the need for community and stakeholder support in biodiversity conservation, but also accepts the degraded nature of many of the Basin's rivers.

It will be important to integrate the demonstration-reach management framework with existing land and water programs, as a means of demonstrating the ability to rehabilitate fish habitat and populations, while allowing sustainable levels of resource use to continue. Local steering committees and project officers will be instrumental in activating linkages with community groups such as the education sector, Landcare, catchment management agencies, local government, indigenous groups, anglers, conservation groups and landholders. Further links with industry may include farming, irrigation, commercial fisheries and tourism.

Relationship between demonstration reaches and freshwater protected areas

Clarifying the relationship between a demonstration reach and a reserve will be important for maintaining community support, given the widespread concern over factors such as reduced access to areas under 'protection'.

The design and implementation of a 'knowledge-transfer program' would promote rehabilitation reaches and convey the benefits of conserving native fish. This implies the use of the demonstration reach as a tool for raising public awareness and highlights its role as providing the groundwork for establishing a system of reserves. The temporary nature of the demonstration reach (i.e. 5 to 10 years – even 10 years may be too short to demonstrate ecological benefits) could be considered a key difference from the relative permanence of a reserve. The reserve would also be protected by legislative power, which the demonstration reach may lack. Table 4 summaries the difference between demonstration areas and freshwater protected areas.

Table 4. Differences between demonstration reaches and freshwater protected areas (FPAs)

Category	Demonstration reaches	FPAs
Purpose	foster community support; increase community awareness; rehabilitate fish habitat	protect and conserve fish habitat, and communities; provide for species and habitat management
Usage	sustainable levels of usage would remain unchanged except in special circumstances where threatening processes are particularly severe and can be mitigated with relative ease	reserves may differ in their level of protection and usage; adoption of a hierarchical structure of usage levels similar to IUCN protected area categories
Timeframe	temporary and dependent on status of reach (i.e. for five to ten years)	permanent and binding
Responsibility	community and stakeholders, State and local federal agencies	Federal and State Government (Fisheries and conservation agencies
Resources required	knowledge transfer program; interventions, developing and maintaining stewardship	site investigation; declaration; plan preparation; 'enforcement'
Legislation	management to fit within existing legislative framework	may need to be formulated or tailored
Quantity	determined by availability of sites and resources; should be distributed through jurisdictions	to meet requirements of CAR, should represent each aquatic ecosystem (i.e. upland, lowland, wetland, billabong, etc.)
Size/scale	dependent on site and resources, though 20–100km river reach is typical	dependent on site and resources

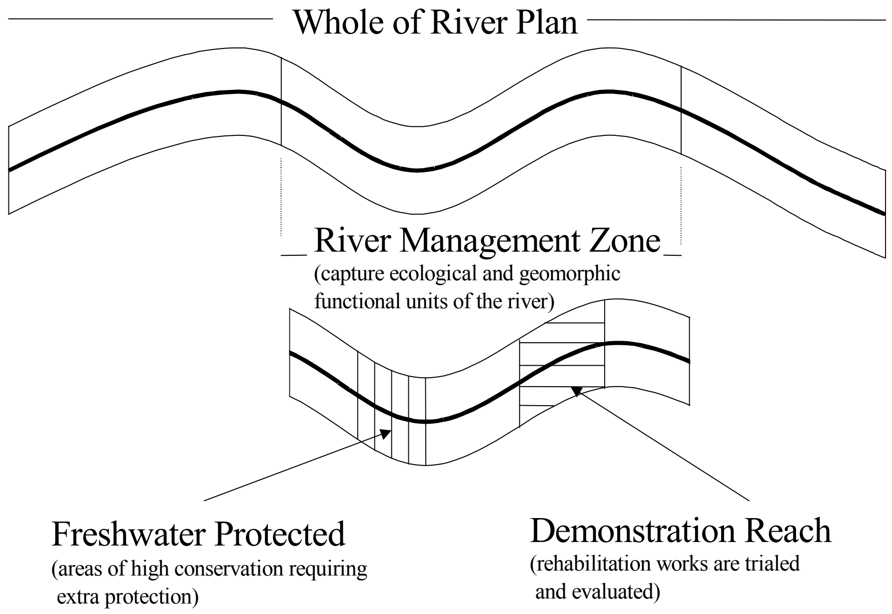

Fig. 2. Relationship among RMZs, FPAs and demonstration reaches.

Although the goals of a demonstration reach are to increase community awareness, provide support for native fish and establish rehabilitation works, the goal of the reserve is to protect and maintain habitat and fish populations over the long term through management plans and legislative tools. In some instances, where a new 'type' of habitat or community is proposed for protection, the demonstration reach may become eligible for declaration as a reserve. This may occur after successful rehabilitation and through support from the community and legislative frameworks.

Difficulties in management arising from the size and complexity of freshwater systems may be overcome by splitting them into smaller management units, such as the River Management Zones (RMZs) proposed in the NFS. These units capture the geomorphological and ecological function of the river, with the establishment of a protected area or demonstration reach within each RMZ being a priority (Fig. 2).

The role of adaptive management

Given the lack of rigorous scientific baseline data and the uncertainty of many factors inherent within aquatic systems, such as the interactions between native and non-native species, dispersal patterns and responses of fishes to the provision of habitat, rehabilitation may follow an active adaptive-management framework. Adaptive management addresses the need to accept that knowledge of the systems being managed is always incomplete. It pursues an integrated experimental design allowing clear separation of the effects of as many changes as possible, so that a sensible balance of management tools and policies can be developed (Braysher and Barrett 2000).

The rehabilitation of habitat and fish populations within the demonstration reaches under a framework of adaptive management would accommodate a dynamic system resulting from natural interactions and human influence. This "licence" to proceed without complete knowledge of the system encapsulates the 'precautionary principle' and is particularly significant for freshwater ecosystems, given the degraded nature of the rivers in question, as well as the poor conservation status and lack of biological and ecological data of many species. The latter was outlined by a recent survey of threatened fish in the region (Morris *et al.* 2000).

This approach uses management policies as experimental treatments to be implemented in a manner that allows statistically valid tests of the results (Wilhere 2002). The successful adoption of an adaptive-management framework requires the systematic acquisition of reliable information (Wilhere 2002). This may take the form of careful long-term monitoring of the effects of different management strategies on the target species, population, community or ecosystem, depending on the scale examined and the management objectives attached. The use of active adaptive management within the demonstration reach, although initially costly and labour intensive, may provide valuable insight into the behaviour of these degraded systems. It would therefore allow prioritisation of threatening processes to be mitigated in other areas.

CASE STUDY – THE OVENS RIVER

The feasibility of the demonstration-reach concept was explored in a hypothetical case study applied to a section of the Ovens River in north-eastern Victoria, Australia. The Ovens River catchment covers an area of approximately 778,000 ha and is unique in that it is one of the least-regulated rivers in the Murray–Darling Basin. The section of the river nominated as a potential demonstration reach for the purposes of the case study extends from the township of Wangaratta to the headwaters approximately 90 km upstream. Several factors warranted its selection, including the wide variety of land uses and resultant impacts on the riverine environment, the heterogeneity of land tenure, and the diversity of both alien and native fish species, the latter including nine threatened taxa.

Threatening processes

The area has a number of potential threatening processes common to many riverine ecosystems within the Murray–Darling Basin. These are summarised in Table 5. This reach of the Ovens River has undergone extensive modification largely through 'river improvement works' resulting in a simplified channel lacking large woody debris (Cottingham *et al.* 2001). Removal of woody debris or snags (de-snagging) from the river channel was carried out officially until about 10 years ago, but anecdotal evidence and observation suggests that it is still practised.

Some landholders believe that snags accelerate erosion through the damming effect on river flow, and that this floods areas of their land. The local Catchment Management Authority (CMA) may therefore be placed under pressure by a small number of landholders to remove snags or realign them with the direction of water flow. Snags left in place are often insignificant in terms of size or structural complexity. Compounding the effects of removal of snags is a reduction in 'recruitment' of new snags from the existing degraded riparian zone.

Sedimentation due largely to mining operations in the 1900s has also led to a loss of instream habitat, which may have direct effects on aquatic fauna with a high degree of habitat specificity such as the two-spined blackfish (*Gadopsis bispinosus*). It may also alter the macroinvertebrate assemblages, and so have flow-on effects to native fish through a change in prey. What remains is a largely homogeneous, sediment- or gravel-covered riverbed in many places, lacking snags and depth variability and therefore decreased habitat complexity.

Although there are no large impoundments on the Ovens River itself, several potential barriers to fish passage exist within the proposed reach. These include structures such as weirs for irrigation and water supply for urban consumption. None of the structures provide any means of mitigation, and all seemingly present considerable barriers to native fish passage. Long stretches of the river lacking instream habitat such as snags and rocks may also form barriers to fish passage.

Table 5. Ovens River – Summary of threats to native species

Threat	Action required
Loss of instream habitat de-snagging sedimentation	Habitat rehabilitation. Re-education re-snagging and better enforcement of legislation protecting habitat bank stabilisation
Alien species	Management plan to reduce effects Education re detrimental effects of species translocations
Riparian degradation	Management of exotic plant species, fencing and revegetation, and community education Enforcement of vegetation clearance controls.
Poor summer environmental flows	Review of summer water extractions and maintenance of adequate flows
Reduced water quality	Riparian zone rehabilitation as buffer strip
Barriers to fish passage	Installation of fishways and other mitigation action

Also notable is the degradation of the riparian zone in many parts of the river. This is due largely to the direct removal of vegetation for agriculture, the grazing of livestock to the stream bank and the planting of exotic species. This planting culminated in the removal of native *Eucalyptus* trees and replacement with rows of willow and cottonwood trees along extensive sections of river frontage. Some management activities are in place to eradicate certain species such as the black willow (*Salix nigra*). Other exotic species that have infested sections of the riparian zone include blackberry and privet as well as other garden exotics particularly around urban areas.

The issue of environmental flows is the subject of debate in the region and is under review. The diversity of human activities in the catchment places a great demand on the system's water resources. Many regard the tobacco industry a major water user, and a recent report listed urban water use as constituting 25% of usage levels (SKM 2001). Over-commitment of summer water allocations is a key environmental issue (SKM 2001). Seasonal considerations in the maintenance of flows are crucial, given the movements of native fish for spawning (e.g. Murray Cod spawning in late winter/early spring).

In addition to the threats outlined above, a number of alien fish species inhabit the proposed reach of the Ovens River. Carp, redfin, oriental weatherloach, rainbow trout and brown trout are present in the system. Carp numbers are reportedly lower than in past years, but are spread throughout the river with no known management activity in place. Removal of carp represents an issue raised repeatedly with the Victorian Department of Natural Resources and Environment (DNRE) by recreational anglers. Another important matter for the local recreational angling community is the continuity of trout populations. Their presence is of great recreational value to this group, but forms a potential conflict of interest when the aim is to conserve native fish fauna. Though trout have traditionally been stocked into the system, the population has been deemed self-sustaining and stocking may only proceed now in the case of a 'disaster' that alters abundances.

Water quality, particularly within the proposed reach, is typically good, though high turbidity and nutrient concentrationss have been identified as the main parameters of concern (SKM 2001; Cottingham *et al.* 2001).

Stakeholder attitudes and perceptions

Representatives of various stakeholder groups were consulted to determine their perceptions and values of the river and its native fish fauna, as well as their levels of support for the demonstration-reach concept (see Table 6). These groups included State agencies, local government, landholders, recreational anglers and Landcare groups. It is recognised, however, that a more comprehensive consultation process would need to be undertaken, engaging a wider range of stakeholder groups prior to implementation of the project.

Table 6. Summary of issues raised by stakeholder groups in relation to implementation of a demonstration reach on the Ovens River, Victoria.

Stakeholder group	Issues raised
Recreational anglers	Removal of trout Environmental flows De-snagging Presence of exotic species Concern over potential access restrictions
Landholders	Lack of faith in Government handling and of rehabilitation efforts Local Government not interested in conservation Environmental flows Problems in conveying benefits of rehabilitation efforts to other landholders Scale of proposed reach too large
State Government agencies (e.g. DNRE Fisheries)	Inadequate funding and resources for enforcement of imposed regulations within demonstration reach Heterogeneity of land tenure creating difficulties in enforcement Exotic species Degraded riparian zone
Local Government	Funding Difficulties with land tenure
Community groups (e.g. Landcare)	Need for a holistic approach Need for simple, uncomplicated management Opposition from some to willow removal

As expected, stakeholder attitudes and perceptions varied both between and within groups, with associated values being determined largely by their association with the river. Concern was raised by nearly all consulted that the notion of a demonstration reach would preclude access either to the riparian zone in the case of landholders, or to the river itself in the case of recreational anglers. The latter group also expressed concern that implementation of such a plan would involve removal of trout from the system and were adamant that such a move would meet extreme opposition. In the upper sections of the Ovens River, trout support a substantial tourism industry. Members of some of these recreational angling groups showed interest in the health of the system as applied mainly to trout habitat, with some having participated in stream rehabilitation efforts in other areas of the catchment.

A Fisheries Officer with the Victorian DNRE, in constant contact with this interest group, also listed the issue of trout as potentially problematic. In addition, the frequent requests from anglers for additional fish stockings into the system were noted, an indication that many believe that supplementing the population, as opposed to habitat rehabilitation, is the answer to declining fish numbers.

A small cross-section of local landholders expressed support for the concept of demonstration reaches and for the rehabilitation of native fish habitat and populations, in contrast to the stereotypical view that landholders are concerned with little but their own financial security at the expense of the environment. The group expressed a considerable degree of stewardship; however, their main concern was a lack of trust towards Governments handling the proposed revegetation works. Instead it was suggested that the landholders themselves carry out these works under guidelines set by resource managers.

Another issue raised was the physical size of the demonstration reach (~90 km), which was thought to be too great. It was suggested that a project of this scale would most certainly encounter uncooperative landholders. Some suggested a ‘start small and work up’ approach, commencing works on the frontage of cooperative landholders, and allowing others to progressively agree and so expand the area of rehabilitation. It is important to note that the stakeholders consulted represent only a relatively small proportion of the inhabitants of the Ovens catchment – for example, the association of the landholders interviewed with the Landcare movement may have constituted a biased sample. The present exercise was limited by time constraints, but a well designed and well analysed, large-scale survey may overcome this problem.

Establishment of a demonstration reach

Ideally, the use of a demonstration reach on the Ovens River would not only facilitate rehabilitation of fish habitat and populations, but would fit within existing management frameworks. It would also incorporate the needs and address the concerns of major stakeholder groups. Priority, however, should lie in rehabilitating fish habitats and populations. This necessitates the removal or mitigation of the threatening processes discussed above. This would involve, concurrently, the following: rehabilitation of the riparian zone; provision for fish passage such as the installation of fishways on all formidable barriers; rehabilitation of instream habitat such as re-snagging and placement of rocks; management of alien species; maintenance of adequate environmental flows; and continued monitoring of water quality with mitigation where necessary.

Rehabilitation of instream habitat has been shown to have benefits in previous studies conducted within the Ovens River. Koehn (1987) reported a marked increase in densities of the two-spine blackfish with the provision of artificial habitat. Replacement of rocks may therefore be seen as a beneficial rehabilitation activity within the demonstration reach, as would re-snagging be, given the reliance of species such as Murray cod on woody debris. Revegetation and protection of the riparian zone would ensure continued ‘recruitment’ of woody debris. This, coupled with landholder education on the importance of snags, could increase instream habitat for fish. Somewhat problematic is the issue of the mobilisation and deposition of sediments and its smothering effects on fish habitat, possibly requiring extraction of sediments where their accumulation as a result of human activity is evident. Again, rehabilitation of the riparian zone would restore this natural buffer and reduce further sediment input.

Demarcation of the proposed reach, in this instance the section of the Ovens River upstream of the township of Wangaratta, is the first step in the process. This includes the associated riparian zone under ownership of the Crown, which presents a problem in itself given the uncertainty within many sectors over land tenure owing to the dynamic nature of the river. Changes in river course can result in shifts in ownership between the landholder and the Crown depending on whether the change is gradual or sudden (i.e. in the event of floods).

In the case of Crown-owned river frontage leased to the landholder, buyback options could be explored to initiate stock exclusion and revegetation of the riparian zone where voluntary cooperation is not forthcoming. Alternatively, revegetation activities may be conducted within existing willow-management frameworks. This would follow the same strategy of dealing with cooperative landholders initially and allowing for a spread in realisation of the benefits to further individuals. An aspect less easily overcome, and one that may form a significant barrier to progress in the rehabilitation of the riparian zone, is the illegal clearing of Crown land adjacent to the river. Evidence of this has been seen in the area. The only solution may be education on the importance of riparian zones combined with enforcement of legislation with adequate prosecution where necessary.

On-ground revegetation activities may be conducted by community members, local government, conservation groups and Landcare members with government funding. Some of the landholders want to carry out revegetation on their own properties, so guidelines for revegetation might be provided. This would be in addition to the supply of necessary materials. In areas where the river flows through genuinely private land, tax incentives or some other reward scheme may be established to encourage rehabilitation. The resultant revegetation would benefit terrestrial organisms as well.

Control of alien species must be considered a high priority within demonstration reaches, because transferring knowledge of, and interest in, native fish should be a goal of any associated management plan. The presence of non-native species can present both a direct and an indirect threat to native species. The Stream Management Program of the Ovens Basin Water Quality Strategy lists control of carp as a management priority (OBWQWG 2000); therefore, management objectives within the demonstration reach may be addressed by activities carried out under this plan. Recreational harvest of fish within the demonstration reach may continue in accordance with fisheries policy, pending investigation into the status of fish populations and reassessment of sustainable yield. From this it may be decided that present levels of harvest remain, or that recreational angling continue though with the adoption of a 'catch-and-release' policy. The selection for this policy would be species-dependent and could be temporary until a species reaches a suitable abundance.

If an adaptive management strategy is to be pursued, long-term monitoring of the effects of different management activities on the target species, population, community or ecosystem is required. Monitoring exercises could be carried out by State agencies such as DNRE, by nongovernmental agencies such as universities or consultancies, or by trained conservation volunteers. This will allow prioritisation of threatening processes to be mitigated in other areas.

Existing legislation

As mentioned, successful implementation of the demonstration reach will rely on minimising disturbances to the existing infrastructure and the community. This may necessitate managing the demonstration reach within existing legislation, a requirement that may both benefit and hamper rehabilitation efforts. Current legislation includes measures to prevent the release of fish into protected waters (*Fisheries Regulations 1998*); the declaration and management of 'fisheries reserves' (*Fisheries Act 1995*); the determination and protection of 'critical habitat' (*Flora and Fauna Guarantee Act 1988*); control of noxious weeds and pest animals (*Catchment and Land Protection Act 1994*); and encouragement of community participation in the management of land and water resources (*Catchment and Land Protection Act 1994*).

Community/stakeholder involvement

Community awareness and involvement could be enhanced through the dissemination of information regarding the status of native fish habitat and populations. For example, a newsletter updating progress of fish populations in the demonstration reach could be circulated. Posted signs may advise anglers and other recreational users on both the native and non-native species present and relevant regulations on the purpose and benefits of the demonstration reach, and encourage their participation in rehabilitation activities. Coverage of activities in the local rural newspaper may also assist in gaining community support. In addition, community participation in rehabilitation efforts could be facilitated through open days or 'meet and greet' days where members of the public can interact with fisheries scientists and resource managers. The involvement of schools and other education institutions may also be a practical and positive part of the process, including the possibility of students' 'adopting' a stretch of the demonstration reach.

Through these activities a greater understanding and sense of stewardship for the aquatic environment could be fostered. Community involvement on a voluntary basis would not only harness awareness and possibly continuing support, but also potentially reduce costs of rehabilitation works. This may be achieved through the formation of volunteer-based or partly funded fish habitat rehabilitation groups. These groups would be made up of community members, landholders, recreational anglers and other interested parties with a resource manager as facilitator. The underlying focus of all this activity should be to develop strong and on-going partnerships.

SYNTHESIS

The hypothetical demonstration reach on the Ovens River examined here appears to be both practical and feasible, with proposed management activities capable of incorporation into, or alignment with, existing activities. Achieving the objectives of rehabilitation of native fish habitat and communities will involve the formulation of a management plan that is adaptive in nature and incorporates existing administrative and management frameworks. This will require the implementation of a long-term monitoring program of sufficient duration to accommodate the life histories of many species and environmental stochasticity, and designed to provide scientifically robust data. Some key stakeholders consulted demonstrated strong support for the concept and expressed interest for the rehabilitation of fish populations. The successful implementation of a management plan and a resultant increase in quality of habitat and growth of fish populations may elevate the status of the Ovens River demonstration reach to enable transformation, possibly through the State's Heritage Rivers Act 1992, into a freshwater protected area for the purpose of protection of fish habitat and communities.

DISCUSSION

There is a clear mandate for a system of freshwater protected areas in the Murray–Darling Basin (MDB). The various legislative provisions, policies and commitments referred to in this paper constitute a moral, as well as a legal, responsibility to develop such a system. Established reserve hierarchies for the conservation of both terrestrial and marine biodiversity in Australia demonstrate what can be achieved with adequate commitment and resources.

The primary constraints to the establishment of such a system appear to be (*i*) perceived lack of government support; (*ii*) lack of suitable sites; (*iii*) perceived lack of community support and (*iv*) a reluctance to commit to an initiative that may "lock up" parts of riverine systems that are being used to maximum capacity. We shall briefly discuss these points.

Firstly, existing legal obligations for a system of FPAs have been highlighted in other papers in this volume (e.g. Nevill 2003). The 2001 Fenner Conference on the Environment called for, as a top national priority, the State and federal agencies to work together to establish an enduring series of special catchments for the management of biodiversity. It also recommended that the federal environment agency (Environment Australia) should "coordinate the development of an interim biogeographic regionalisation of inland waters to complement those already developed for terrestrial and marine systems, as a basis for allocating priorities and resources at national and regional scales." (Georges and Cottingham 2002).

In addition, the NFS argues that "There is a need for specific habitat types in good condition to be protected so that the needs of native fish species, including their lifecycle requirements are met", but that "the determination of such reserves is difficult given the flowing nature of water, the movements of fish and the close interaction between such aquatic habitats and adjacent land areas." (MDBC 2002).

In relation to the lack of suitable sites, it has been well documented that a significant proportion of the MDB, including the riverine system, is degraded. Essentially there are two dilemmas. Firstly, a disproportionate amount of the "lowland" part of the system, especially the Murray River itself, is likely to be unworthy of providing adequate sites suitable for selection as FPAs. Secondly, although there are greater opportunities for suitable sites, in terms of habitat, in the upland areas, in reality many of these stretches have depleted native-fish numbers and are dominated by introduced species. A representative system of reserves, whether or not adopting the bioregional approach, needs to address these issues.

Community support for a system of FPAs is essential to its success. As well as the general public, particular sectors (especially river "users" such as recreational and commercial fishers, farmers and irrigators) and umbrella groups such as catchment management organisations and Landcare groups need to be actively engaged. The Ovens River experience suggests that there is a considerable and sometimes surprising level of support for such a system. This is particularly the case when sufficient time is allowed for the concept to be discussed and to mature, and for the benefits to be properly explained. These sectors (and governments) need to be reassured that a system of FPAs will not, except in exceptional circumstances, prevent "wise use" of the designated river reach (or wetland system) including fishing and other recreational uses, water extraction, etc. A hierarchy of reserves as proposed in this paper, following broad IUCN guidelines, should provide for variation within, as well as between, reserves.

The lack of currently available sites, and the critical role of the community in river rehabilitation, highlights the potential for an 'intermediate' step such as the use of demonstration reaches in establishing a system of FPAs. However, there appear to be two overriding pitfalls that need to be addressed in the planning and implementation of demonstration reaches. Firstly, the concept of adaptive management needs to be employed in its true sense. There has been a tendency in the past decade to use this term quite loosely and to justify inappropriate, but convenient, management planning actions, with little or no subsequent monitoring or evaluation.

Secondly, demonstration reaches must be planned in the context of other regional strategies for the catchment or river reach, in order to maximise the resources available, avoid duplication, engage the community, and achieve natural resource management.

CONCLUSIONS

It is a pragmatic reality of government funding regimes and the overriding political climate that demonstration reaches are attractive propositions. They involve the community, integrate regional planning and resources, and demonstrate positive results. This is despite the fact that such initiatives effectively constitute planning from the "bottom up".

Importantly, this suggests a real chance of creating FPAs in the lowland areas of the MDB, through a process of rehabilitation and involving significant community input. Such areas might otherwise have been precluded from a system of because of their degraded nature and failure to meet associated criteria for site selection. It will be especially critical to include wetlands as part of the demonstration reach / freshwater protected area system. Of course, demonstration reaches may also be required for upland rivers.

A demonstration reach can be the basis of a FPA if

- the community is supportive and involved in all stages of the project,
- the proposed restorative actions are integrated into local and regional plans,
- the likelihood of long-term benefit to native fish communities and habitat is high,
- there is ongoing government support, and
- the "rehabilitation" is successful.

In the Ovens River experience, the benefits of community consultation were exemplified in the identification of key management issues early in the process. The existence of significant support from the community, adequate legislative and managerial frameworks, the high visibility of the site and the importance of its fish assemblage begs the establishment of a demonstration reach to rehabilitate this valuable commodity.

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RIVERINE AQUATIC PROTECTED AREAS: PROTECTING SPECIES, COMMUNITIES OR ECOSYSTEM PROCESSES?

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Abstract

Freshwater ecosystems are subject to a greater range and intensity of direct and indirect pressures than many other ecosystems. Rivers are linear with no immediate upstream or downstream boundaries, long 'edge effects', and many aspects of their functioning are dependent on catchment and land management issues occurring outside the immediate riverine area. Australia has a low diversity of freshwater fish species, so protection is of high importance for this component of biodiversity. The objectives for riverine aquatic protected areas should be to protect species, ecological communities and ecological processes. How well protected areas realistically meet these objectives is the key question. This issue is discussed using a 200 km reach of the Murray River from Yarrawonga to Barmah as an example. This river reach contains a critically endangered species (the trout cod), a listed aquatic community and is influenced by a range of altered ecological processes and threats, including barriers to fish passage, altered water flows, angling and habitat degradation. It appears that a riverine aquatic protected area may be able to provide some protection for some species and some of their habitats, but additional management actions may need to be undertaken outside the protected area to address some threats, especially those affecting wider ecosystem processes.

Keywords: freshwater, Murray River, aquatic protected areas, communities, ecosystem

INTRODUCTION

Protected Areas are seen as an integral part of conservation management although their roles are often not explicitly defined. Terrestrial reserves have an extensive theoretical basis for their design and include concepts from island biogeography, patch dynamics and genetics (Meffe and Carol 1994). Such a framework is still in its infancy for marine reserves (Allison *et al.* 1998) and designs drawn from experiences in the terrestrial realm may not be valid owing to differences in scale and variability (Steele 1985). Riverine Aquatic Protected Areas (APAs) are, however, a new concept with little available theoretical basis for their design.

In south-eastern Australia, the objectives of key biodiversity and river restoration strategies include the protection of species, ecological communities and ecological processes (Natural Resources and Environment 1997; Murray–Darling Basin Commission 2002). APAs are one of the actions identified to achieve these objectives (Murray–Darling Basin Commission 2002). In this paper I explore the realistic levels of protection that could be afforded these different ecological units within a riverine APA, using an example reach on the Murray River in south-eastern Australia.

Riverine ecosystems

The nature of freshwater ecosystems means that these are subject to a greater range and intensity of direct and indirect pressures than many other ecosystems. Rivers are linear systems with no immediate upstream or downstream boundaries, and have long 'edge effects' with many aspects of their functioning dependent on catchment and land management issues occurring outside the immediate riverine area. The linear nature of any riverine reserve leaves it susceptible to the impacts of actions that may occur upstream, downstream or in its catchment, often outside any protected zone. Rivers can flow across different management zones and State jurisdictions, often leading to less than uniform management objectives.

THE MURRAY RIVER

The Murray River is one of the world's longest rivers, flowing over 2500 km from source to the sea. It is heavily regulated with two major water storages (Hume Dam and Dartmouth Dam) in its upper reaches. The main channel forms a major conduit for the delivery of irrigation water to downstream reaches. The Murray–Darling Basin Commission, through a range of multi-State agreements that include water provisions for South Australia, controls water within the River. Regulation means that there have been many changes to the flow regimes including reductions in overall river mouth outflows, reductions in flooding and seasonal flow reversals (Close 1990). The Murray River forms the State boundary between New South Wales (NSW) and Victoria, with jurisdiction over the river being controlled by NSW.

Aquatic species

Most attention to date has focussed on the larger aquatic vertebrate species, mainly fish, despite the fact that more than 439 different types (or taxa) of aquatic macroinvertebrates have been collected from the Murray River (Bennison and Suter 1990). The number of fish species in the Murray River is relatively low by world standards, containing only about 30 native species, several of which are restricted to the lower river zones and associated with marine or estuarine reaches (Koehn 2002). Several groups undergoing taxonomic revisions may yield new species. Although this number of species may be expected of a river with a relatively low overall discharge, it is dramatically lower than the 1300 fish species described for the more tropical Amazon Basin (Cadwallader and Lawrence 1990). Eight introduced fish species are also present in the Murray River. Although floodplain and aquatic plants are recognised as key components of the riverine ecosystem these are not considered in this paper.

Table 1. Conservation status of freshwater fish species of the Murray River (Yarawonga to Barmah) (modified from Koehn 2002).

* = past distribution only; EPBC = *Environment Protection and Biodiversity Conservation Act 1999*, ASFB = Australian Society for Fish Biology 2001 listing; CE = critically endangered; E = endangered; V = Vulnerable; Epop = endangered population in New South Wales; FFG = listed under the *Flora and Fauna Guarantee Act*, Victoria; P = New South Wales Protected species (i.e. no take); (P) = Protected from commercial take; Broad-finned galaxias is a coastal native species introduced into the upper Murray River (Waters *et al.* 2002).

Common name	**Scientific name**	**Listing**			
		National		**Vic**	**NSW**
Native freshwater species		**EPBC**	**ASFB**		
Short-headed lamprey	*Mordacia mordax*				
River blackfish	*Gadopsis marmoratus*			DD	
Broad-finned galaxias	*Galaxias brevipinnis*				
Flat-headed galaxias	*G. rostratus*		V	DD	
Mountain galaxias	*G. olidus*			DD	
Murray cod	*Maccullochella peelii peelii*	V		V, FFG	
Trout cod	*M. macquariensis*	E	CE	CE, FFG	E,P
Golden perch	*Macquaria ambigua*			V	
Macquarie perch*	*M. australasica*	E	E	E, FFG	V,P
Silver perch	*Bidyanus bidyanus*		V	CE, FFG	V,P
Southern pygmy perch	*Nannoperca australis*				V
Australian smelt	*Retropinna semoni*				
Freshwater catfish	*Tandanus tandanus*		V	V, FFG	(P)
Bony herring	*Nematalosa erebi*				
Southern purple spotted gudgeon*	*Mogurnda adspersa*		E	CE, FFG	Epop
Carp gudgeons (species complex)	*Hypseleotris* spp.				
Flat-head gudgeon	*Philypnodon grandiceps*				
Dwarf flat-head gudgeon	*Philypnodon* sp.			FFG	
Crimson spotted rainbowfish	*Melanotaenia fluviatilis*			DD, FFG	
Murray hardyhead	*Craterocephalus fluviatilis*	V			
Non-specked hardyhead	*C. stercusmuscarum fulvus*			E, FFG	E
Introduced species					
Brown trout	*Salmo trutta*				
Rainbow trout	*Oncorhynchus mykiss*				
Carp	*Cyprinus carpio*				
Tench	*Tinca tinca*				
Goldfish	*Carassius auratus*				
Redfin (English perch)	*Perca fluviatilis*				
Gambusia	*Gambusia holbrooki*				
Weatherloach	*Misgurnus anguillicaudatus*				

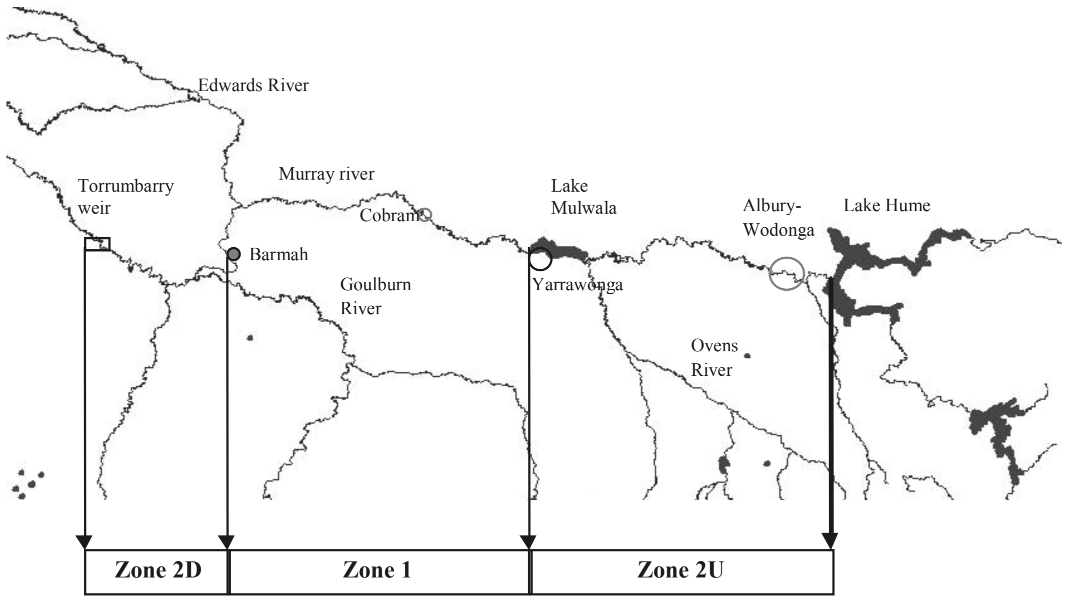

Fig. 1. Site map of the study reach under consideration for an Aquatic Protected Area and adjoining reaches of the Murray River.

Most native fish species in the Murray River have, however, suffered major declines over the past 50 years (e.g. Cadwallader 1978, 1981; Cadwallader and Gooley 1984; Harris and Gehrke 1997). The causes of such declines include changes to flows, habitat alterations, interactions with exotic species, cold-water pollution, barriers to movement and overfishing (Cadwallader 1978; Koehn and O'Connor 1990a; Kearney *et al.* 1999). There is concern about the long-term future of many species, with seven fish species being considered nationally threatened (Koehn 2002). This includes the critically endangered trout cod, *Maccullochella macquariensis* (Australian Society for Fish Biology 2001), whose natural range is now restricted to the river reach considered in this paper. Of particular community concern is the decline of many 'flagship' species such as Murray cod, *Maccullochella peelii peelii*, trout cod, silver perch, *Bidyanus bidyanus*, and catfish, *Tandanus tandanus* (Table 1). Commercial fisheries for such species have all been greatly reduced or ceased (Reid *et al*. 1997). Recreational angling remains popular for native species such as Murray cod and golden perch *Macquaria ambigua* although the capture of trout cod and silver perch is now prohibited. Whilst abundance and distribution for most native species have declined, small areas such as Lake Mulwala still provide anglers with productive native fish fisheries.

The study reach

The 200 km reach of the Murray River from Yarrawonga to Barmah (Fig. 1) illustrates the practicalities of what could be achieved in a riverine protected area. This river reach has already been suggested for consideration as a Freshwater Aquatic Reserve (Hankinson and Blanch 2002) and has natural assets including:

- The only natural remaining population of the critically endangered trout cod;
- Representation of a listed aquatic community (Table 2);
- Excellent instream habitats;
- Good native fish populations, especially compared with upstream and downstream reaches;
- Largely intact riparian zones and floodplains;
- The Barmah–Millewa forests; and
- Culturally significant areas.

Substantial data for this reach as a scientific study site (Koehn and Nicol 1998; Koehn *et al*. 2000; Nicol *et al*. 2001) and baseline ecological data could be used as a reference for rehabilitation of other river reaches, e.g. demonstration reaches (Murray–Darling Basin Commission 2002; Barrett and Ansell in press).

Nineteen species of native fish currently reside in the study reach (Table 1) and are an important component of the biodiversity, ecology and culture of the Murray River. A key feature of the study reach is Lake Mulwala, which is used to feed irrigation water from the river to the Mulwala and Yarrawonga irrigation channels (Jacobs 1990). These channels can take up to 50%

of the river inflows during an average irrigation season (C. Fitzpatrick, pers. comm.).

Major inflowing tributaries include the Ovens (largely unregulated) and Goulburn (largely regulated) rivers, with the Edwards River being the major outflowing tributary (Fig. 1). In order to address the issues and influences on the study reach, consideration is given to four zones:

Zone 1: Yarrawonga to Barmah;

Zone 2U: Upstream – Yarrawonga to Lake Hume;

Zone 2D: Downstream – Barmah to Torrumbarry; and

Zone 3: Whole of river – upstream of Lake Hume, downstream of Torrumbarry.

Table 2. Species of the aquatic ecological community in the natural drainage of the lower Murray River catchment. * = proposed or listed threatened species under the Threatened Species Schedules of the *Fisheries Management Act 1994.* # = fish species included in the *Flora and Fauna Guarantee Act* listing for the Lowland riverine fish community of the southern Murray–Darling Basin (this listing also includes *Macquaria australasica,* Macquarie perch). The total species list of this community is much larger. Only fishes, most macro-molluscs and most macrocrustaceans have comprehensive listing (New South Wales Fisheries 2002).

Fish	
Mordacia mordax (Short-headed lamprey)	#*Nematalosa erebi* (Bony bream)
Galaxias olidus (Mountain galaxias)	#*Galaxias rostratus* (Murray jollytail)
Retropinna semoni (Southern smelt)	#*Tandanus tandanus* (Freshwater catfish)
*#*Craterocephalus fluviatilis* (Murray hardyhead)	#*Craterocephalus stercusmuscarum fulvus* (Non-specked hardyhead)
#*Melanotaenia fluviatilis* (Crimson-spotted rainbowfish)	*#*Ambassis agassizi* (Olive perchlet)
*#*Maccullochella macquariensis* (Trout cod)	#*Maccullochella peeli peeli* (Murray cod)
#*Macquaria ambigua* (Golden perch)	*#*Macquaria australasica* (Macquarie perch)
**Nannoperca australis* (Southern pygmy perch)	*Gadopsis marmoratus* (River blackfish)
*#*Bidyanus bidyanus* (Silver perch)	#*Hypseleotris klunzingeri* (Western carp gudgeon)
Hypseleotris sp. 4 (Midgleys carp gudgeon)	*Hypseleotris* sp. 5 (Lake's carp gudgeon)
*#*Mogurnda adspersa* (Purple-spotted gudgeon)	#*Philypnodon grandiceps* (Flat-head gudgeon)
Philypnodon sp. (Dwarf flat-head gudgeon)	
Crustaceans	
Austrochiltonia australis (water scud)	*Paratya australiensis* (freshwater shrimp)
Austrochiltonia subtennuis (water scud)	*Macrobrachium australiense* (freshwater prawn)
Bosmina meridonalis (water flea)	*Cherax destructor* (Yabbie)
Daphnia lumholtzi (water flea)	*Euastacus armatus* (Murray cray)
Boeckella fluvialis (copepod)	*Tachea picta* (shrimp lice)
Caridina mccullochi (fresh water shrimp)	*Heterias pusilla* (freshwater slater)
Insects	
Antiporus femoralis (water beetle)	*Micronecta gracilis* (Water bug)
Antiporus gilberti (water beetle)	*Microvelia paramoena* (water bug)
Chironomus cloacalis (midge)	*Xanthagrion erythroneurum* (dragonfly)
Coelopynia pruinosa (midge)	*Hemicordulia tau* (dragonfly)
Cryptochironomus grisiedorsum (midge)	*Austrogompus cornutus* (dragonfly)
Kiefferulus martini (midge)	*Notostricta solida* (dragon fly)
Procladius paludicola (midge)	*Anisocentropus latifascia* (caddis fly)
Tanytarsus fuscithorax (midge)	*Ecnomus pansus* (caddis fly)
Micronecta annae annae (water bug)	*Hellyethira eskensis* (caddis fly)
Molluscs	
Alathyria condola (bivalve)	*Austropeplea lessoni* (snail)
Alathyria jacksoni (bivalve)	*Glyptophysa gibbosa* (snail)
Corbiculina australis (bivalve)	**Notopala sublineata hanleyi* (snail)
Sphaerium problematicum (bivalve)	*Thiara balonnensis* (snail)
Sphaerium tasmanicum (bivalve)	*Velesunio ambiguus* (bivalve)
Other	
Ephydatia ramsayi (freshwater sponge)	*Brachionus falcatus* (rotifer)
Eunapius fragilis (freshwater sponge)	*Brachionus novaezealandia* (rotifer)
Heterorotula contraversa (sponge)	*Microscolex dubius* (oligochaete worm)
	Temnocephala chaeropsis (flatworm)

Table 3. Ecological unit definitions and process requirements.

Ecological unit (Boulton and Brock 1999)	**Definitions** (Lampert and Sommer 1997)	**Ecosystem processes** (Lampert and Sommer 1997; Boulton and Brock 1999)
Species		
Individual	Single organism.	Metabolic rates, reproduction, movement.
Population	A group of individuals of the same species that occupies a particular location at a given time.	Population growth, recruitment, recolonisation, competition.
Community	The sum of all the interacting populations in the habitat.	Interactions (competition, predation, symbiosis).
Ecosystem	The comprehensive unit of communities and their interactions with the abiotic environment.	
Biotic	From living organisms.	Energy production and transfer, trophic levels/food chains, nutrient cycling, biodiversity, biogeographic patterns, evolution, succession, habitat inputs.
Abiotic	From non-living factors.	Hydrology, flows, wind, light, temperature, chemical and physical processes and cycling (e.g. oxygen, pH, N, erosion, sedimentation).

MANAGING ECOLOGICAL UNITS

Protected areas may be established for their habitats, 'naturalness', scientific or recreational values, biodiversity/conservation, profile, etc. Marine reserves protect critical areas, provide refuge for intensely exploited species and act as buffers against management miscalculations (Allison *et al.* 1998). Hankinson and Blanch (2002) have suggested the establishment of different classifications of freshwater reserves with different degrees of protection. Whatever the degree of protection, or the objective of the APA, to achieve the best ecological outcome we need to consider the level of ecological unit that we are trying to protect. Ecological units range from individuals, to populations, to communities, to ecosystems. Each of these ecological units has linkages to other ecological units and is associated with a range of habitats and processes integral to its wellbeing (Table 3).

Conservation management has moved largely from a species-by-species approach (managing individuals and single species) to one in favour of communities and ecosystem protection. Preservation of ecosystems "protects more human values, serves wider human goals and ultimately, saves more species than do expensive efforts to save species" (Norton 1986). In order to achieve this objective, there needs to be an understanding of the associated ecological processes.

Protecting species

Protection of individual species has usually been the first step in most statutory protection. The Murray River's low diversity of freshwater fish species heightens the importance of protection for the species-level component of biodiversity. Species are conserved because these are rare, threatened, endemic, large, attractive or of recreational or economic importance. Some species should, however, be conserved because of their disproportionate effect on the persistence of all other species – 'keystone' species (Bond 1994). This term was first used to describe marine predators, but such species can be any 'whose activity and abundance determined the integrity of the community and its unaltered persistence through time, that is community stability (Paine 1966, 1969). The interactions of such species may be complex, subtle or difficult to define, but this approach perhaps belies the need to look beyond the protection of single species towards their interactions with other species and the ecosystem. Ehrlich and Ehrlich's (1981) 'rivet hypothesis' in which they likened species to the rivets on an aircraft – if you lose enough then you crash – did not specify whether all rivets had the same structural importance. It is unlikely that all species have equivalent functions, and it is the ecological functioning that we should concentrate on protecting. 'Keystone' species in this reach may be Murray cod, as a top-level predator, or perhaps the freshwater shrimp *Paratya australiensis,* an abundant macroinvertebrate.

'Keystone' species have not been formally designated for the Murray River, but there may be other ways in which the protection of individual species can be of importance. Murray cod is likely to be a 'focal species' (Lambeck 1997) which can be used to represent the needs of several other species that may be susceptible to similar threatening processes (e.g. trout cod or golden perch). The public identification with such a 'flagship' species would assist with such wider protection.

Table 4. Movement patterns of fish species in the study reach (from Cadwallader and Backhouse 1983; Koehn and O'Connor 1990b).

A - within Zone 1	***B - into adjacent Zones 2U and 2D***	***C – whole of river***
River blackfish	Broad-finned galaxias	Short-headed lamprey
Flat-headed galaxias	Murray cod	Golden perch
Mountain galaxias		Silver perch
Trout cod		Bony herring
Southern pygmy perch		
Freshwater catfish		
Carp gudgeons		
Flat-head gudgeon		
Dwarf flat-head gudgeon		
Australian smelt		
Murray hardyhead		
Non-specked hardyhead		
Crimson spotted rainbowfish		

A fundamental assumption of protected areas is that these will protect populations within their boundaries. But what if the species moves outside these boundaries, even if only for a component of its life cycle? For many fish species, components of the life cycle (eggs, larvae, juveniles, or adults) may not remain within the limits of a riverine protected zone.

Patterns of population replenishment for fish species fall into four categories (Carr and Reed 1993):

a) Short-dispersal species, which have populations that can be considered self-replenishing at the reserve scale;

b) Limited-distance dispersers, which may disperse beyond the reserve boundaries, but into areas mostly adjacent to the reserve;

c) Longer dispersals – which may have only one or a few actively recruiting populations and rely on the source population for replenishment; and

d) There may be several populations that all supply recruits to a common larval pool.

Species in the study reach can largely be categorised into A, B or C (Table 4).

About 30% of the fish species present will not reside permanently within Zone 1. Therefore, these species cannot be protected within this APA alone. The movement requirements of most of these species are, however, unknown (Koehn and O'Connor 1990b). In addition, many of the other species exhibit larval drift (Koehn and Nicol 1998; Humphries and Lake 2000), which is largely unquantified in terms of percentage of larval population involved or the distances travelled downstream. This means that the limited movements (A) categorised for several species may really apply only to their adults. Mallen-Cooper *et al.* (1995) found large numbers of juvenile silver perch moving upstream through a fishway, presumably to recolonise. The short-headed lamprey, *Mordacia mordax,* also has a marine phase to its lifecycle. In such cases, consideration may need to be given to establishing separate APAs to protect different life stages. Most of the aquatic invertebrates are relatively sedentary and are likely to be able to be protected within the APA (Suter and Hawking 2002; P. Suter pers. comm.).

Threatened species (see Table 1) rarely occur just in one zone. Although Zone 1 contains the only remaining natural population of trout cod, many actions have been suggested and implemented in an attempt to recover this species (Brown *et al.* 1998). These include the protection of another translocated population and attempts to establish further populations through restocking. There is the potential for the Murray River trout cod population to expand outside Zone 1 both upstream and downstream. The protection of trout cod in an APA would assist this expansion providing greater numbers of individuals to assist in the establishment of new populations. The taking of trout cod by anglers is prohibited, but mortalities may occur though accidental capture and it has been recognised that this population is sensitive to any increases in mortalities (Todd *et al.* in press).

Furthermore, the objectives of protected areas should be to protect not only species but also adequate amounts of the habitats that they use. This should include protection of areas such as the adjoining floodplain. Although to date there is little evidence for use of the floodplain by fish (Humphries *et al*. 1999), it may be important for a range of processes such as the supply of nutrients.

Protecting ecological communities

There is an increasing view that ecological communities should receive more attention for protection rather than individual species. If the goal of the protected area is to protect and support a broad range of species, then the range of complex interactions between these species (competition, predation, and symbiosis) needs to be taken into account and the priority should be to protect the community rather than single species. Ecological communities are also considered under threatened-species legislation, with the 'Lowland Riverine Fish Community of the Southern Murray–Darling Basin' listed under the *Flora and Fauna Guarantee Act* in Victoria and 'The aquatic ecological community of the Lower Murray, Murrumbidgee, and Tumut Rivers' (New South Wales Fisheries 2002) listed under the Threatened Species Schedules of the *Fisheries Management Act* in New South Wales (Table 2).

It is clear that not all components of the ecological community always remain within Zone 1 (Table 4). Thus, whereas most members of the aquatic community would be protected by an APA at the scale of Zone 1, others such as the mobile fish species would not. The roles of particular functional groups (e.g. top-level predators) in maintaining ecosystems are important but are rarely considered when protecting individual species. This oversight may be corrected by protecting communities, which would incorporate functional roles and interactions. Protection of aquatic communities such as those listed, cannot be undertaken without consideration of the threats that are imposed upon them (see below). These threats are considered in a draft recovery plan for Lowland Riverine Fish Community of the Southern Murray–Darling Basin (Brown *et al.* in press) and the 'Native Fish Strategy 2003-2013 for the Murray–Darling Basin' (Murray–Darling Basin Commission 2003). These measures address a wider range of issues, threats and actions across the Basin including consideration of socio-political issues.

APAs can protect some components of aquatic communities. In the study reach, about 50% of adult fish species may be protected, but some larvae and juveniles may not be. Protection levels for the aquatic invertebrate community will be much higher.

Protecting the ecosystem and biological processes

The concept of ecosystem management is based on the survival of a species being inherently intertwined with the survival of many other species in the same ecosystem. Species and biodiversity will be conserved only through the conservation of habitats and ecological communities in which the species live (Miller 1996), so it is also necessary to ensure that the processes that ensure the functioning of the ecosystem are maintained.

Properties of ecosystems and ecosystem processes are a function of abiotic factors and biotic ecosystem components. The complexities of such interactions usually mean, however, that the understanding of ecosystem processes and their influences on management is less than that of individual species. Ecosystem processes include both static and dynamic interactions and include primary production and consumption, secondary production, energy and nutrient flows, biogeochemical cycles, succession, and other processes that structure communities. These processes and those relating to species and community functioning (Tables 3 and 5) underpin the ecosystem and its biodiversity. In particular they support ecosystem resilience, which is the ability of the system to recover after disturbance (Schlapper and Schmid 1999). This functional approach to biological conservation assures the resilience of ecosystems (Folke *et al.* 1996). For ecosystem function to be maintained, a minimum composition of organisms is required to develop trophic relationships to mediate energy flow and the cycling of elements (Folke *et al.* 1996), but this must be accompanied by the maintenance of physical processes such as provision of light or water flow.

Although ecosystems and ecosystem processes are not specifically protected by legislation, the listing of Potentially Threatening Processes under threatened-species legislation is intended to address threats that largely alter ecosystem processes.

The *Flora and Fauna Guarantee Act* in Victoria lists the following Potentially Threatening Processes that relate to riverine ecosystems:

- Alteration to the natural flow regimes of rivers and streams*;
- Alteration to the natural temperature regimes of rivers and streams;
- Degradation of native riparian vegetation along Victorian rivers and streams*;
- Increase in sediment input into Victorian rivers and streams due to human activities;
- Input of toxic substances into Victorian rivers and streams;
- Introduction of live fish into waters outside their natural range within a Victorian river catchment after 1770*;

Table 5. Key threatening processes for the river zones within the study reach and their impacts on species, communities ecosystem processes and adjoining river zones. * = present in that zone.

Key threatening processes	Zone 1	Zone 2U	Zone 2D	Species	Community	Ecosystem process	Effect on adjoining river zones?	Solution in Zone 1?
1. Constant flows	*	*	*			Yes	Yes	No
2. Unseasonal high flows	*	*	*			Yes	Yes	No
3. Reduction in flooding	*	*	*			Yes	Yes	No
4. Reduced floodplain linkages	*	*	*			Yes	Yes	Yes
5. Cold water pollution		*			Yes	Yes	Yes	No
6. Snag removal		*	*	Yes	Yes	Yes		Yes
7. Riparian grazing	*	*	*			Yes		Yes
8. Barriers		*	*	Yes	Yes	Yes	Yes	No
9. Fishing	*	*	*	Yes	Yes	Yes		Yes
10. Exotic species	*	*	*		Yes	Yes	Yes	Partly

- Prevention of passage of aquatic biota as a result of the presence of instream structures; and
- Removal of wood debris from Victorian streams*.

* Similar processes are listed under the *Fisheries Management Act 1994* in New South Wales

Recent scientific assessments of flow and environmental impacts along the Murray River (Jensen *et al.* 2000; Thoms *et al.* 2000) highlight how threats change through the river reaches. Most of the key threatening processes identified for the river zones considered in the study reach (Table 4) have more direct impacts at the ecological process level than for the community and species levels. Few of the solutions available are from actions that may be undertaken only within Zone 1. Hence, to protect ecological processes within the APA, actions outside the APA also need to be undertaken. Processes that are protected at the APA scales (e.g. recruitment of some species) not only benefit the APA but also the adjoining reaches.

Focal species such as Murray cod may be used to highlight the importance of addressing threats. The protection and use of an individual species can therefore assist in the protection of community and ecosystem processes if the threats are clearly identified. Some threats, however, have outcomes that are not so obvious. For example, if turbidity is increased, then productivity may be reduced and sight-feeding fish disadvantaged. The impacts of threats such as cold-water pollution, which reduces the spawning success of many species in Zone 2U (Koehn 2001) but has largely dissipated when water reaches Zone 1, may still affect the population and community of Zone 1 through reduced recruitment from upstream.

Solutions that can realistically be achieved by management actions undertaken at the APA scale include habitat protection (snags, riparian zones and floodplains) and restrictions on fishing. Cold-water pollution (which affects Zone 2U) could be addressed by remedial actions undertaken at Lake Hume. Exotic species need to be addressed at a wider scale (Carp Control Coordinating Group 2000) although actions in some specific areas (such as Barmah for carp, *Cyprinus carpio* (Stuart *et al.* 2001) may have greater impacts. Restrictions to fish passage due to barriers can be addressed at a local level although the benefits are unlikely to apply beyond the immediate reach. For example, the fishway at the Torrumbarry weir (downstream end of Zone 2D) allows fish to move upstream into Zone 2D and Zone 1. The operation of the fish lift installed at Lake Mulwala will allow fish to move upstream from Zone 1 into Zone 2U. Lake Hume remains a barrier at the upper reach of Zone 2U. Most issues relating to river flows need to be addressed at a scale beyond that of an APA.

Management of ecosystem processes also requires an understanding of the concept that ecological change can be episodic rather than gradual. Ecosystem change happens at a range of scales and ecosystems do not necessarily have a single equilibrium, so are moving targets for management. Therefore, management needs to be adaptable. Episodic events such as floods may be important for the resetting of system processes, but many of these mechanisms are not well understood. An APA may provide an ideal location to investigate the influence of various management regimes on ecosystem function.

MEASURING THE EFFECTS OF THE PROTECTED AREA

Depending on the limitations of activities within the protected area, some additional pressures may be placed on the environments outside the protected area. For example, if angling were to be banned, then some of the existing angling pressure might transfer to adjacent areas that might not be able to cope. Similarly, what will be the effect of the provision of upstream fish passage via the fish lift at Lake Mulwala on the existing fish populations downstream in Zone 1? The success of any APA needs to be monitored both within and outside the area to which actions are applied. APAs may therefore provide opportunities to investigate and monitor the effects of management changes, e.g. the implementation of a fishing ban on populations.

CONCLUSION

Riverine APAs are an essential component of conservation because these can provide protection of unique critical areas, habitats and some localised species. In this study reach, a protected area would provide protection for most invertebrate species and up to 70% of fish species present. A protected area provides insufficient protection alone, however, for mobile species and for threats that can impact on them from outside their boundaries. As APAs are not isolated from, but can be affected by external threats, these threats also need to be addressed to protect wide-ranging species and so that the effectiveness of the APA itself is not compromised. Ecosystem processes cannot be managed at the APA scale but, in addition to the measures undertaken within the APA, must be addressed at the larger scale to ensure that the APA is protected. APAs will not be effective for threats such as water-quality issues, changes in climate, invasion by exotic species, or spread of diseases. Many of the actions that are required for APAs should be considered for the whole river system to ensure the restoration of native fish populations (Murray–Darling Basin Commission 2003). The use of 'flagship' species to promote APAs and their protection may be useful because 'Protecting fishes will help to protect aquatic biodiversity, ecosystems and invertebrates (Moyle 1995).'

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LONG-TERM VISUAL AND ACOUSTIC CETACEAN SURVEYS IN KOMODO NATIONAL PARK, INDONESIA 1999-2001: MANAGEMENT IMPLICATIONS FOR LARGE MIGRATORY MARINE LIFE

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Abstract

Komodo National Park and World Heritage Area (KNP) is located between Sumbawa and Flores, Indonesia. To assess KNP's ecological significance for large migratory species of special concern, visual and bio-acoustic cetacean surveys have been conducted twice yearly to a) identify which cetacean species are present in KNP and obtain data on relative species abundance, seasonality, critical habitats, tourism potential and environmental impacts; b) Involve KNP stakeholders in cetacean monitoring programs.

In the 1999-2001 survey periods a total of 18 cetacean species were identified during 207 survey hours over 71 field days during 5 field seasons. The surveys covered 4706 nautical miles. Species encountered were predominantly oceanic odontocetes, but also included balaenopterid whales. An estimated total of 7082 individual cetaceans were sighted during 299 encounters. Acoustic contact with cetaceans was recorded during 38.1% of all listening stations. Major species-specific results include relative abundance indices, site preferences and calving rates. Critical habitats including migration corridors have been identified. Environmental impacts observed include reef bombing and other fisheries interactions. Cetacean watching potential has increased, however this would not be an appropriate tourism activity without strict controls. Extensions to KNP's boundaries have been incorporated in the 25-year management plan to include preferred cetacean habitats. Continued surveys are paramount for existing or new MPA management plans, cetacean conservation measures and national policies, as well as alternative livelihood options. This is especially so for MPAs in eastern Indonesian island passages which function as Indo-Pacific marine corridors for large migratory marine life, such as the Solor-Alor region.

Keywords: Komodo National Park, cetaceans, surveys, marine corridors, Indonesia

THE CETACEAN SURVEY PROGRAM IN KOMODO NATIONAL PARK AND WORLD HERITAGE AREA

Indonesia has an exceptional cetacean (the collective name for all whales and dolphins) diversity and a preliminary review of cetaceans sighted in Indonesian waters lists 29 species, while the occurrence of three other species was still unconfirmed (Rudolph *et al.* 1997). More than one-third of all known whale and dolphin species worldwide can be found in the Indonesian Seas, including numerous rare and endangered species (IUCN 1996). Cetacean habitats include major rivers and mangroves as well as coastal and open ocean environments. These diverse habitats are often in close proximity to one another because of Indonesia's narrow continental shelf, abundant oceanic islands and extreme depth gradients (Tomascik *et al*. 1997). Research on Indonesia's cetacean species diversity, abundance and distribution is especially important when considering the nation's complex geographical and oceanographic characteristics. Indonesia is uniquely located as the only equatorial region worldwide where inter-oceanic exchange of marine flora and fauna occurs. Cetacean movements between the tropical Pacific and Indian Oceans can occur through the passages between the Lesser Sunda Islands which span over 900 km between the Sunda and Sahul shelves (Klinowska 1991). In this region of eastern Indonesia, a strictly limited number of deep inter-island channels are known or suspected to function as migration corridors for cetaceans (PHPA 1984; Kahn 2002b). The ecological significance of these passages remains poorly understood, yet all Indonesia's cetacean populations, transient and resident, which include these passages in their local or long-range movements are vulnerable to numerous regional and local environmental impacts such as habitat destruction, net entanglement, marine pollution and over fishing of marine resources (Hofman 1995, Kemp 1996, Fair and Becker 2000), subsurface noise disturbances including reef bombing (Ketten 1998; Kahn *et al.* 2000), as well as directed catches for local consumption and bait for the shark long-line fishery (Barnes 1991, 1996; Kahn 2002a).

Komodo National Park (KNP) is part of the Lesser Sunda, or Nusa Tenggara, island chain and is located between the islands of Sumbawa and Flores. KNP includes three inter-island straits and is of importance to the conservation of Indonesia's terrestrial as well as marine biodiversity (Pet and Djohani 1996). Komodo National Park encompasses 603 km² of land and 1,214 km² of marine waters. It contains three large islands (Komodo, Rinca and Padar) and many smaller islands. The Komodo area was established as a National Park in 1980 by the Government of Indonesia and declared a Man and Biosphere Reserve and a World Heritage Site in 1986. The region includes three major island passages which provide access for migratory marine life from the Indian Ocean and Sumba Sea to the other Indonesian Seas and the western Pacific. Its World Heritage Area status reiterates the importance to "ensure the identification, protection, conservation, presentation and transmission of world heritage values to future generations" (UNESCO 1972). The key survey objectives of the KNP cetacean rapid ecological assessment program are:

1. To provide base-line data on cetacean diversity, distribution and abundance in all marine habitats of Komodo National Park (KNP) including:
   i. **Coastal habitats** of KNP to monitor the presence of vulnerable coastal cetaceans.
   ii. **Inter-island straits** and deep channels of KNP to examine their significance as migration corridors for wide-ranging migratory cetaceans occurring in eastern Indonesian waters.
   iii. **Oceanic areas** to the north and south of KNP to monitor the presence of oceanic cetaceans.
2. To monitor seasonal patterns in KNP cetacean diversity, distribution and abundance to identify resident or transient populations.
3. To identify critical habitats for cetaceans, including preferred feeding grounds, mating locations and migration corridors.
4. To identify and assess the major local and regional environmental impacts that threaten eastern Indonesia's whales and dolphins.
5. To evaluate which protective measures can be implemented by Park management authorities to minimize the environmental impacts on cetacean habitats, including coral reefs, mangroves and the open ocean.
6. To establish community-based cetacean monitoring programs, as well as outreach activities, through the active participation of management agencies and stakeholders including:
   i. TNC-Komodo Field Office staff.
   ii. Balai Taman Nasional Komodo rangers.
   iii. Komodo National Park dive operators.
   iv. Local communities and fishermen.
7. To provide site and species-specific information on KNP cetaceans for:
   i. Marine resource and park management purposes.
   ii. Environmental awareness and educational programs.
   iii. Support to the Park's marine tourism and dive industry.
8. To share the survey results and research outcomes with the Indonesian National Park Authorities, environmental organisations and local communities.

SURVEY METHODS AND RESEARCH ACTIVITIES

Survey method I: TNC speedboats

The majority of the periodic 15-day visual and acoustic cetacean surveys were carried out from a 25-foot TNC Yamaha speedboat cruising at 16-18 knots. The surveys focused on the coastal areas, bays and inter-island passages of Komodo National Park, as well as the adjacent offshore waters of the Flores and Sumba Seas. While underway, a minimum of two experienced observers conducted visual surveys of the surrounding waters. If cetaceans were sighted the vessel's course and speed were adjusted to allow for a discreet approach and close observation. Whenever possible a positive species identification (ID) was made. Unidentified cetacean encounters were recorded as such after a minimum of 10 minutes of visual survey efforts focused on obtaining a positive identification. Unidentified cetacean encounters were usually the result of unfavourable light conditions, sea state, lack of proximity, active avoidance behaviour or operational constraints.

Standardised waterproof data sheets were used to record time, sea surface conditions, GPS location, species sighted, estimated abundance, group composition, the presence of newborn calves, minimum distance from vessel, direction of travel, species associations and a suite of selected behaviours. A Nikon 601 SLR camera equipped with a Nikkor 70-300mm lens was used to obtain multi-species photo-identifications of individual animals with distinctive colourations, marks or scars. In addition, a Sony PC-10 digital video camera was also frequently used to record the diversity of cetacean species and behaviours. After the ID and data recordings were completed, the vessel departed from the sighting area at a reduced speed and resumed the predetermined survey route. During offshore routes, the visual surveys were complimented by periodical acoustic listening stations using a directional Vemco VHLF hydrophone (20Hz-20KHz) or Burns Electronics custom hydrophone (30Hz-20kHz) with amplifier. Acoustic surveys were conducted only if the vessel was located four or more nautical miles (nm) offshore to minimise any coastal interference. Listening stations were conducted every 30 minutes, or approximately 7-8 nautical miles apart depending on offshore conditions. Acoustic contacts with priority species were digitally recorded with a Sony Portable MiniDisc Recorder (MZ-R70). The survey commenced in the early morning departing from The Nature Conservancy - Komodo Field Office in Labuan Bajo, located on Flores Island in the Nusa Tenggara Timor province of eastern Indonesia and returned before sunset each day.

Survey method II: Local live-aboard vessels

Visual and acoustic cetacean surveys were also carried out from local live-aboard vessels, usually for 5-day periods. Use of the live-aboard increased the coverage to remote areas and allowed the surveys to continue during less optimal weather conditions. The data collection procedures did not differ between survey methods. The vessel speed averaged 6-7 knots. Increased observer height and regular use of 40x8 marine binoculars increased the visual survey range. The majority of the acoustic surveys were conducted while on-board the live-aboard vessel. Listening stations were conducted on the hour for at least five minutes. Stations were only conducted when located more than 4 nautical miles (nm) offshore to minimise disturbance. Stations were spaced approximately 6 nm apart.

SURVEY RESULTS

All cetacean sighting coordinates of the May 1999 - April 2001 survey periods were transcribed to a GIS format and assigned species-specific data points (Fig. 1). Cetacean species were colour-coded and allocated the following symbols:

Category	Symbol
Sub-order Mysticeti - baleen whales	✯
Families Physeteridea and Kogiidae - sperm whales	🖽
Family Ziphiidae - beaked whales	🎧
Family Delphinidae - dolphins	π
Globicephalinae - a Delphinidae subfamily of six species*	🖩
Unidentified small cetacean (< 6 metre)	ρ
Unidentified large cetacean (> 6 metre)	⌧

*- The Globicephalinae subfamily is based on a systematic revision of the Delphinidae and includes six species: *Feresa attenuata, Peponocephala electra, Globicephala macrorhynchus* and *G. melas, Pseudorca crassidens* and *Griseus grampus* (LeDuc *et al*. 1999). It replaces the historical blackfish category that includes the majority of these species as well. For the Indonesia cetacean surveys, Globicephalinae sightings are recorded when sightings of members of the subfamily can not be identified to species. This occurs infrequently and is due to the similarities of *P. electra, F. attenuata* and juvenile *G. grampus,* in particular during unfavourable sighting conditions.

In the May 1999 - April 2001 survey periods a total of 18 cetacean species (Table 1) were identified during 207 survey hours over 71 field days during 5 inter-monsoon field seasons. The species encountered were predominantly oceanic odontocetes, but also included two balaenopterid whale species. The visual and acoustic survey results are summarized (Fig. 2a-h). The surveys covered an estimated distance of 4706 nautical miles and 553.25 active survey hours. An estimated total of 7082 individual cetaceans were sighted during 299 encounters. Acoustic contact with cetaceans was recorded during 38.1% of the 217 listening stations. The mean number of sightings per survey day equaled 4.2 encounters (range 1.7 - 5.3) for the May 1999 to April 2001 period (Fig. 3a). On all but one KNP survey day (26/05/99) cetaceans were encountered. Estimated mean abundance per sighting ranged from 17.9 to 27.8 individuals per encounter per survey and was calculated at 23.7 for the whole period (Fig. 3b). *T. truncatus* and *S. longirostris* dominate the distribution of sightings within KNP borders (Fig. 1). In the eastern part of KNP at the entrance of Selat Molo and near Nusa Kode, pods of *S. longirostris* are especially common (Fig. 1). In the straits and offshore areas adjacent to KNP a more

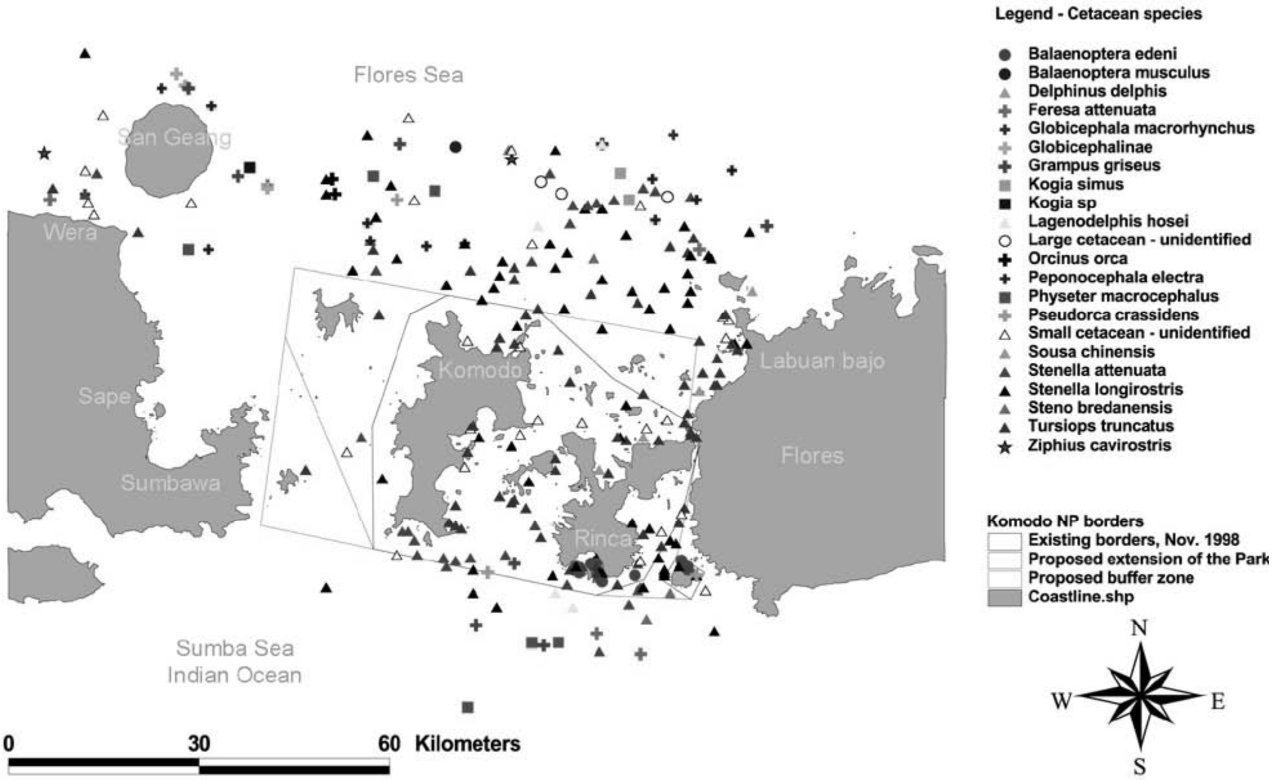

Fig. 1. Cetacean species diversity and distribution in Komodo National Park and adjacent waters May 1999 - April 2001 survey.

Table 1. Cetacean species positively identified in Komodo National Park and adjacent waters for the 1999 - 2001 survey periods.

Cetacean species		**May 1999**	**Oct 1999**	**April 2000**	**Oct 2000**	**April 2001**
Long-nosed spinner dolphin	*S. longirostris*	◆	◆	◆	◆	◆
Bottlenose dolphin	*T. truncatus*	■	■	■	■	■
Pan-tropical spotted dolphin	*S. attenuata*		■	■	■	■
Melon-headed whale	*P. electra*	●	●	●	●	●
Pygmy Bryde's whale	*B. edeni*		●	●	●	
Sperm whale	*P. macrocephalus*	●	●			●
Fraser's dolphin	*L. hosei*		●	●	●	●
Risso's dolphin	*G. griseus*		●		●	●
Pygmy killer whale	*F. attenuata*		○		○	
Dwarf sperm whale	*K. simus*			○		
Pygmy/dwarf sperm whale	*Kogia sp.*	○				
False killer whale	*P. crassidens*	○	○	○		○
Common dolphin	*Delphinus sp.*	○				
Rough-toothed dolphin	*S. bredanensis*		○	○	○	
Cuvier's beaked whale	*Z. cavirostris*		○		○	
Blue whale	*B. musculus*				○	
Orca	*O. orca*				○	○
Short-finned pilot whale	*G. macrorhynchus*					○
Indo-Pacific humpbacked dolphin	*S. chinensis*					○

◆ = Abundant; ■ = Common; ● = Uncommon; ○ = Rare (Categories based on Kahn *et al.* 2000). The *Kogia sp.* sighting is included for completeness but not counted as a positive species identification.

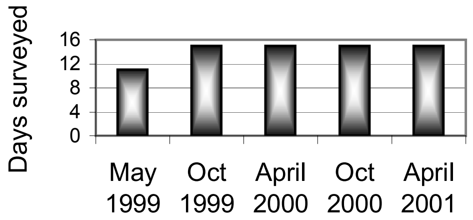

Fig. 2a. Active survey days for each survey period.

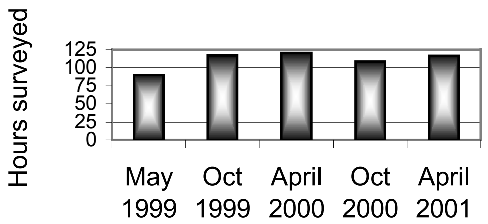

Fig. 2b. Active survey hours for each survey period.

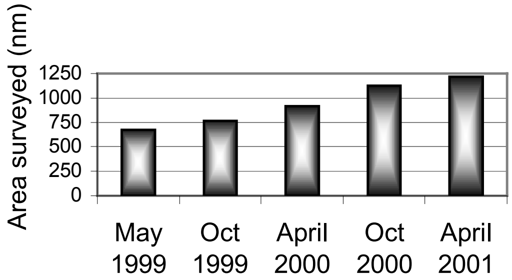

Fig. 2c. Estimated area surveyed for each survey period.

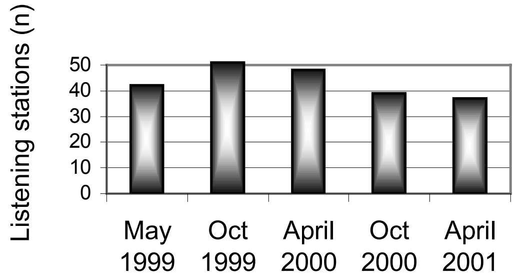

Fig. 2d. Number of listening stations for each survey period.

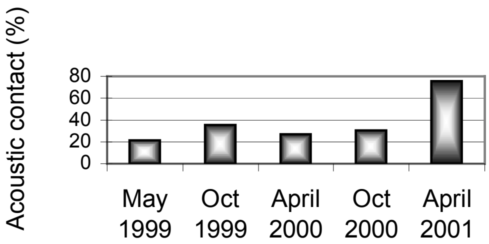

Fig. 2e. Cetacean acoustic contact per listening station for each survey period

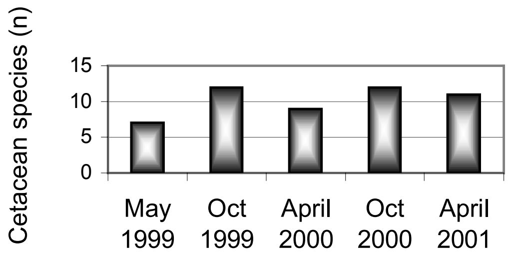

Fig. 2f. Number of species positively identified for each survey period.

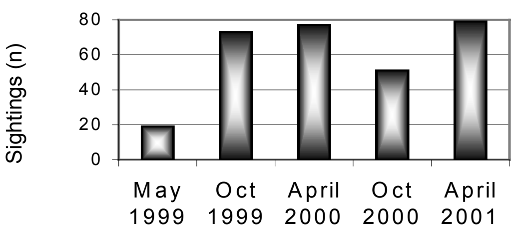

Fig. 2g. Cetacean sighting frequencies for each survey period.

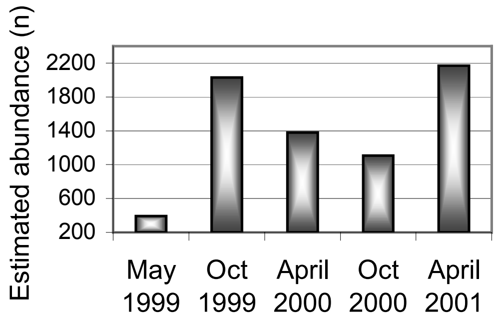

Fig. 2h. Estimated cetacean abundance for each survey period.

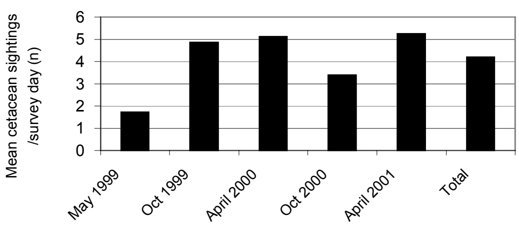

Fig. 3a. Mean cetacean sightings (n) per survey day.

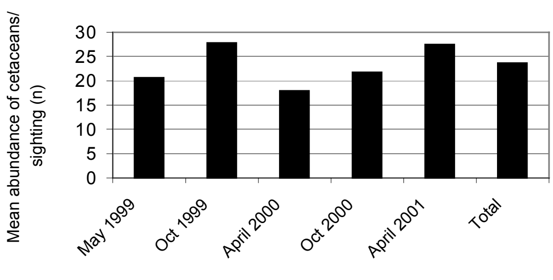

Fig. 3b. Mean cetacean estimated abundance per sighting (n) per survey day.

diverse pattern is becoming evident. Numerous species of oceanic delphinids are abundant in the deeper waters of Komodo National Park. The large and deep expanse of water within KNP borders between Nusa Kode, Padar and south Komodo is frequented by large pods of *S. attenuata*, numbering up to 350 individuals. This part of the Park also inhabits *G. griseus*, *P. crassidens* and occasionally *P. macrocephalus*. The San Geang area presents a marine environment significantly different to all other KNP regions surveyed. It is the only representative of an oceanic volcanic island within survey distance from Labuan Bajo, and records a relatively high number of sperm whale (*P. macrocephalus*), numerous 'blackfish' (Globicephalinae) and occasional orca (*O. orca*) sightings. Ziphiids (*Z. cavirostris*) are regularly sighted in the vicinity of the island. During 1999 and 2000 pygmy Bryde's whales, *Balaenoptera edeni,* have been repeatedly sighted around Gili Mota, and in an inter-island passage between Nusa Kode and south Rinca. Unconfirmed reports from rangers include additional sightings of this species along east Komodo Island, including Loh Namu and Loh Liang. The pygmy Bryde's whale *Balaenoptera edeni*, a regionally distinct baleen whale, was positively identified by photographic and genetic profiling techniques (Kahn *et al.* 2001). This is the first positive identification of a *living* pygmy Bryde's whale with matching photographic data in Indonesia, and possibly SE Asia (Philippine samples come from stranded or harpooned individuals; this species has also been hunted by Japanese whaling vessels in the Solomon Islands, Perrin *et al.* 1996). Thus, the photos and video footage taken of the pygmy Bryde's whales in Komodo could provide an important benchmark for future benign whale research on this data-deficient species in Indonesian waters and SE Asia. The percentage of unidentified small cetaceans is relatively constant for all survey periods to date (mean of 11.7 %) and reflects the challenging survey conditions at sea. Unidentified cetacean encounters can be contributed to unfavourable sighting conditions due to sea state or light conditions, active avoidance or operational difficulties. The summarized survey results indicate considerable variation in both the sightings and abundances between surveys, years and seasons (Fig. 2a-h). This remains the case when the sighting data are corrected for survey effort such as active survey time or distance in nautical miles surveyed (Fig. 4a-b).

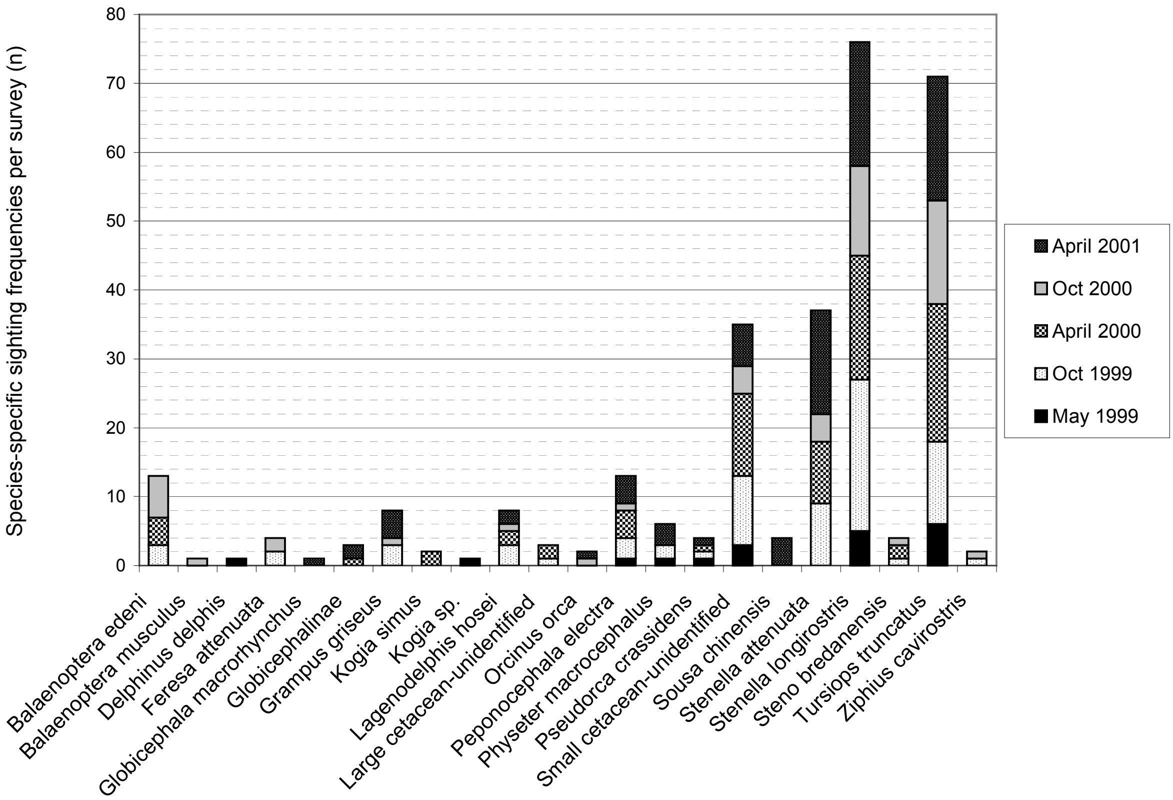

Fig. 4a. Species-specific cetacean sightings (n = 299) for all Komodo survey days to date (n=71).

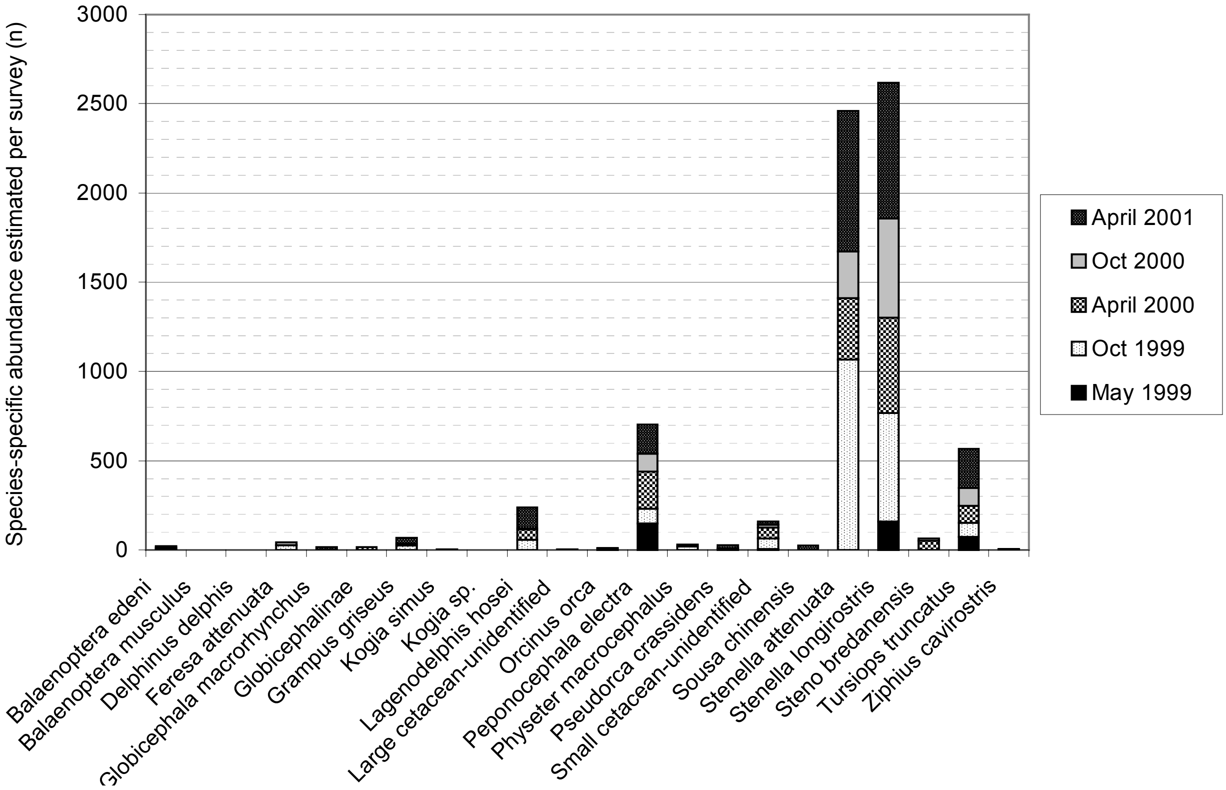

Fig. 4b. Species-specific cetacean abundance (n=7082) for all Komodo surveys days to date (n=71).

Other comparative results are not within the scope of this publication (see Kahn 2001b). The relative abundance estimates of the KNP cetacean species assemblage indicate that the bottlenose dolphin *T. truncatus* and long-nosed spinner dolphin *S. longirostris* are the most abundant KNP species, followed by the pan-tropical spotted dolphin *S. attenuata* and melon-headed whale *P. electra* respectively. Species-specific sighting frequencies and estimated abundances were compiled for the May 1999 - April 2001 survey periods (Fig. 5a-b). During encounters with large migratory cetaceans, survey effort changed priority from rapid ecological assessment (Kahn 2001a, 2002a) to ecological focus research and detailed species-specific behavioural observations (i.e. Whitehead and Kahn 1992; Kahn 1999) by conducting 'group follows' (Mann *et al.* 2000). Such group follows may range from hours to days (visual and acoustic tracking). As these large cetacean species have a relatively low abundance in the survey area, and are often classified as vulnerable or endangered globally, it is considered justified to spend more time for additional data collection with these species of special concern. Ecological focus research provides a context for the initial sighting and habitat preferences of a priority species within the wider survey area. Additional information on (photographic) identification of individuals, local movements, dive profiles and other behavioural activities (indicative of feeding, mating, migrating) and genetic materials (biopsy sampling) was obtained during the group follows. The collection of genetic material depended on the appropriate species encounters, sea state and cetacean sensitivity to vessel approach. Additional sightings of other cetacean species continued to be recorded if such activities did not interfere with the group follows. The May 1999 – April 2001 surveys included several sightings of highly migratory cetacean species including female sperm whales *P. macrocephalus* and immatures of both sexes (also referred to as nursery schools; n=7), socially and sexually mature sperm whales (also referred to as bulls; n=2), orcas *O. orca* (n=2) and a blue whale, *B. musculus* (n=1); an additional blue whale was sighted in the same area during Oct 2001 (Kahn pers.obs). These sightings are of importance to improved migratory marine life management in the Indonesian Seas. All sightings, except encounters with female sperm whale nursery schools in the Sumba Sea, were recorded at the junction of a migratory corridor (Selat Sape) between the Sumba Sea (Indian Ocean) and the Flores Sea (which is part of the Indonesian Seas connecting to the western Pacific). This area of interest is flanked by San Geang and Sumbawa in the west and Banta and Komodo Island in the east. Importantly, even though these sightings span more than two years of periodic survey efforts, the large migratory cetaceans were always sighted near a previous sighting of that same species, and directions of travel were either identical or similar.

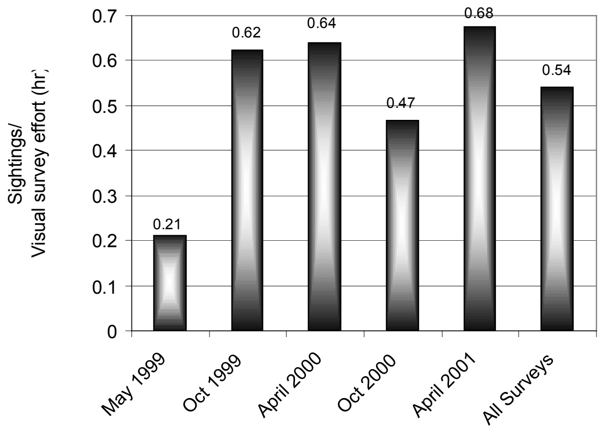

Fig. 5a. Cetacean sightings per visual survey time (hr) for each survey period.

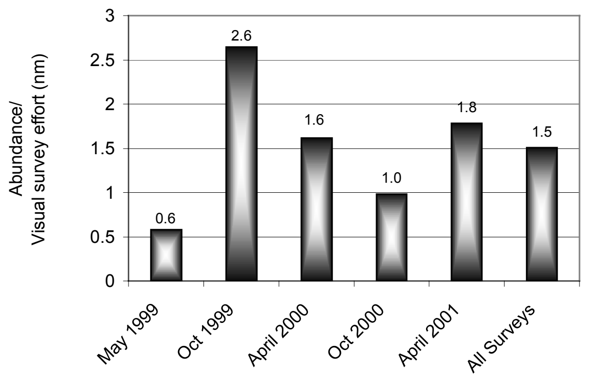

Fig. 5b. Estimated cetacean abundance per visual survey distance (nm) for each survey period.

DISCUSSION

The current state of knowledge on Indonesia's cetaceans is extremely limited and this effectively restricts the capacity for their ecologically based management. The whale and dolphin surveys have greatly increased our understanding of Komodo National Park's significance as an important cetacean habitat (Kahn *et al.* 2000; Kahn 2001b). Newborn calves were observed for seven dolphin species as well as the sperm whale. This indicates that the KNP area could be an important cetacean calving ground. The relative abundance (abundant, common, uncommon and rare), group sizes, as well as habitat preferences have been investigated for eight cetacean species by use of survey encounter rates (Kahn *et al.* 2001) and 'group follows' (Mann *et al.* 2000). This is the first time this kind of species-specific and comparative data has been available for Indonesia.

The substantial variation in cetacean species diversity, distribution and abundance, and lack of annual and seasonal patterns is to be expected for such a relatively short period of data collection, and in accordance with the routine large-scale movements of the majority of the 18 cetacean species observed in KNP waters (i.e. Kahn *et al.* 1993). Even small cetaceans are known to travel extensively within their home range, and often swim over 100km/day (Mann *et al.* 2000). In addition, factors such as prey availability and oceanographic conditions during each survey period will influence cetacean diversity, distribution and abundance in the region. The substantial reduction in sightings and abundance per survey effort for the initial May 1999 period is unclear, but may at least in part be caused by the significant multi-year El Nino Southern Oscillation (ENSO) active at that time. The 1998 La Nina effect could have been responsible for the severely reduced fish catches in the Komodo area in 1998 (Pet 1999), and a similar negative effect on cetacean prey species in this region seems likely. The high values recorded for Oct 1999 and April 2001 may be indicative of favourable ecological and oceanographic conditions for oceanic cetaceans. Additional research into which environmental factors affect cetacean diversity, distribution and abundance in Indonesia is necessary for their effective management and conservation (e.g. Simmonds and Hutchinson 1996). Preferred habitats in and adjacent to KNP waters have been identified for several species of small cetaceans, and the occurrence and behaviour of highly migratory whale and dolphin species in the waters of KNP is consistent with the identification of eastern Indonesia's island passages as migratory corridors of regional conservation significance (PHPA 1984; DKP/IPB 2001). The surveys to date have recorded concentrated sightings of highly migratory cetacean species in the northern entrance of Selat Sape. Although the sample size is still very limiting, blue whales and other highly migratory whale species, including orcas as well as socially and sexually mature sperm whales, or bulls, with an estimated lengths in excess of 16 meters, are repeatedly sighted within close proximity to Banta Island and the Flores Sea (northern) entrance of Selat Sape (the most likely migratory passage in the Komodo National Park research area). All these sightings of highly migratory oceanic cetaceans have occurred in a relatively small geographic area. This sighting pattern strongly indicates that the area is of importance to large migratory cetacean species and underlines the need for additional protection of this area, as proposed by the inclusion of Banta Island and Selat Sape within KNP borders. This management measure for migratory marine species of special concern has been incorporated in the Park's 25-year master plan (Pet and Yeager 2000).

Implications for management of migratory marine life of eastern Indonesia.

The Indo-Pacific migratory passages or 'marine bottlenecks' of Nusa Tengarra in eastern Indonesia may have regional ecological significance as multi-species critical habitats (Kahn 2002d). The extent and intensity of marine exploitation and threats in Indonesia (such as reef bombing as well as numerous other fisheries interactions, see review by Kahn and Fauzi 2001), coupled with the exceptional diversity of cetaceans and other marine life, make it urgent that additional protective management is realized (UNEP/CMS. In press). Hence, the establishment of an Indonesia Marine Mammal Management Area (IMMMA) will be crucial (PHPA 1984; Salm 1984; Kahn 2002c), because for whales and dolphins the impacts on crucial aspects of their ecology often occur outside the current areas of protection. The implementation of an IMMMA with four different management zones is currently under consideration by the Government of Indonesia (Kahn 2002d). On-going cetacean survey and research focus on the Nusa Tengarra island passages in eastern Indonesia are also needed to support both practical and productive migratory species management. This is crucial, because relatively simple conservation measures can be implemented in the passages through site-based programs in the short term which would have a direct and very positive outcome for most of eastern Indonesia's migratory marine mammals. In addition, these outcomes are also beneficial for a myriad of other ocean wanderers sighted in the region (mantas, sharks, whale sharks, sunfish or mola mola, marine turtles, billfish). If such measures are integrated with other pressing coral reef and (coastal and pelagic) fishery issues, the approach also assists with leverage for management options for all marine resources in the same area. These, and other, measures are currently being implemented at Komodo National Park (Kahn and Pet 2001).

Migratory and oceanic habitat conservation opportunities for coastal MPAs

It is important to note that because of the coastal-pelagic habitat proximity for much of eastern Indonesia (as well as Papua New Guinea, the Solomon Islands and other South Pacific island nations), MPA initiatives on migratory marine life, including large whales, can be realistically incorporated into (eco)regional planning. The lack of a significant continental shelf and presence of extreme depth gradients in the majority of this region provide an opportunity to include 'oceanic zones' in future MPA site selection and design for this region, even if the primary aim of those protected areas is to manage reef ecosystems or/and coastal fisheries. Such 'oceanic zones' may include oceanic habitats such as seamounts, oceanic islands and even deep-sea trenches, which may be near the (routinely coastal) management focus of MPAs. This approach would yield major benefits for the management of oceanic protected areas and would by-pass several key challenges associated with (oceanic) MPA establishment and management (e.g. Hyrenbach *et al.* 2000; Roberts *et al.* 2001). For eastern Indonesia's migratory corridors this would be a practical and effective site-based approach to the conservation and management of migratory marine species of special concern – a strategy similar to (and complementary with) protecting the major nesting beaches of marine turtle species – and would provide a field basis in SE Asia to address trans-boundary marine species conservation. This approach is highly recommended for another important cetacean habitat in eastern Indonesia, the Solor-Alor region.

The need for protective marine resource management in the Solor-Alor region

The Solor-Alor region can be considered one of the prime (oceanic) cetacean habitats in the Indonesian Seas (Barnes 1996; Rudolph *et al.* 1997; Kahn 2002b), and possibly even in SE Asia as a whole. Of special interest is not only the high diversity and relative abundance of blue whales and sperm whales and at least 18 other species of oceanic cetaceans in the Solor-Alor region; it also includes several major Indo-Pacific migratory passages, between the islands of Flores, Solor, Adonara, Lembata, Pantar, Alor and importantly, East Timor (i.e. Selat Ombai). The region has a complex oceanography resulting from productive currents of the Indonesian flowthrough and deep-water upwellings of the Savu Sea (Gordon and Fine 1996; Bray *et al.* 1997). Another important aspect of the area is the traditional (sperm) whaling heritage of the Lamalera coastal community, and the continued work with (and research contribution by) this and other coastal communities (Kahn 2002a). The east Flores – west Alor region is not only an exceptional cetacean habitat in the Indonesian Seas. It also has an exceptional abundance of a wide array of other large marine life, including manta rays, (leatherback) marine turtles, bill fish, tuna, mola mola, (whale) sharks and other pelagics. Therefore, an increase in the protective management for marine corridors and other habitats in Solor-Alor is also likely to be of regional significance. However, the concentration of marine resources also makes the region highly vulnerable to increasingly modern and extensive fisheries activities that specifically target mantas, marine turtles, small cetaceans, whales and (whale) sharks. The substantial landings of most target species are of major concern and likely to result in rapid overexploitation of large migratory marine life passing through the area. Hence, continued and expanded conservation efforts are needed urgently in Solor-Alor to a) conserve the exceptional marine life and coastal and marine ecosystems in this remote part of eastern Indonesia and b) assist with the identification and implementation of options for sustainable development and c) promote environmentally sound economic diversification for remote regions of eastern Indonesia. The most effective approach to realise these goals is through the establishment of a Marine Protected Area (MPA). An Solor-Alor MPA could specifically incorporate protective management measures for migratory and resident cetacean populations and other large migratory marine life, as well as coastal resource management and fisheries considerations. Because of the exceptional localized diversity and abundance of large marine life, the establishment of such a MPA in the Solor-Alor region would substantially improve migratory marine life management in the Indonesian Seas. In addition, the establishment of a MPA in the Solor-Alor region would strengthen and complement Indonesia's national conservation and management policy on migratory marine species (DKP/IPB 2001). Such a specific MPA with conservation priorities for migratory marine life incorporated in its management objectives will also act as a catalyst for increased surveys, research and community outreach. In order to protect these highly migratory animals we must know as much as possible about their ecology, population status and dynamics, the locations of their critical habitats, how they use each habitat, when they travel between them and the routes they take. Because of the lack of knowledge on most, if not all, of Indonesia's migratory marine life populations, a habitat focus is considered the most effective approach in providing guidance to short-term conservation and management goals. At the same time, it is important that additional biological research on these species can be conducted in order to address ecological questions of importance to long-term management. The results of the KNP cetacean surveys, as well as those initiated in Solor-Alor more recently (Kahn 2002a) confirm that straits and passages should be considered as *'priority management units for species of special concern'* (Agardy 1997). Site-based marine conservation programs and improved protective management measures for Solor-Alor's and other Nusa Tenggara migratory passages are crucial to the conservation of Indonesia's, and indeed SE Asia's, migratory marine biodiversity.

CONCLUSION

The Komodo cetacean surveys have made a significant contribution to the knowledge of Indonesia's cetacean diversity, distribution and relative abundance. The long-term cetacean surveys have shown that the Komodo region is an important habitat for whales and dolphins, and are an important aspect of resource management plans, conservation measures and alternative livelihood options for marine protected areas in eastern Indonesia. Significant extensions to KNP's legislative boundaries have been designed to include preferred habitats of the Park's cetaceans. These extensions are incorporated in the 25-year management plan and will increase the protective status of cetaceans in KNP and Indonesia. In addition, the positive identification of the pygmy Bryde's whale, a new species for these waters, further increased the exceptional marine bio-diversity of the Indonesian Seas. The experience in Komodo National Park has shown that in eastern Indonesia, cetacean surveys and ecological research can be an important impetus to realise conservation measures, assist with the mitigation of threats in protected areas and provide input to national marine mammal conservation strategies.

The lessons learned in KNP are also important to ensure that effective conservation outcomes can be achieved in other priority cetacean habitats of the Indonesian Archipelago, and may assist with potential site selection and design of additional marine protected areas in eastern Indonesia such as the Solor-Alor region (Barnes 1996, Kahn 2002c), part of the so-called Flores-Banda Seas ecoregion. The Solor-Alor region has an exceptionally high diversity and abundance of large marine life including cetaceans, and numerous vulnerable migratory species are currently under intense fisheries pressure. Improved protective management could be effected in the Solor-Alor region through the establishment of a MPA with a large migratory marine life conservation focus, and include strong coastal resource management and community development components.

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IMPORTANCE OF RECRUITMENT CUES FOR MAINTENANCE OF UPSTREAM POPULATIONS OF DIADROMOUS GALAXIIDS IN PROTECTED AREAS WITHIN NEW ZEALAND

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Abstract

Protection of aquatic areas for management of specific faunal elements requires an understanding of recruitment dynamics for maintenance of population viability. In New Zealand, protected areas that encompass aquatic habitat and contain species of value are often located at higher altitudes and not afforded the luxury of protective status to the sea. Of the 17 *Galaxias* species currently described in New Zealand, five are diadromous and therefore require access to the sea to complete their life cycle. The juvenile migrations of these five species constitute a nationwide commercial and recreational whitebait fishery.

Successful recruitment of juveniles is therefore pertinent to sustaining adult populations in protected headwaters. Recruitment strategies can include the response to both physical and chemical environmental factors. Knowledge of migration cues, which promote recruitment, has implications in the management of fish populations in protected areas. This paper describes published studies that demonstrate juvenile galaxiids can discriminate and are attracted to odours produced by adult conspecifics and indeed the pheromonal attraction exhibited by one species was shown to override an avoidance of suspended sediments.

To maintain protected diadromous fish populations, restoration and provision of suitable habitat may not be enough to positively influence juvenile recruitment, migration cues influencing recruitment to populations through unprotected migratory pathways are often crucial. A published study suggests that pheromonal cues produced by adult conspecifics may enhance the maintenance of adult populations through their encouragement of juvenile recruitment to protected areas upstream.

Keywords: pheromone, recruitment, galaxias, migration, fish

PROTECTED FRESHWATER AREAS WITHIN NEW ZEALAND

Aquatic protected areas can conserve the biodiversity of valuable fish fauna by providing a refuge from environmental change such as habitat degradation through changes in water quality, flow regime, removal of forest or riparian cover, sedimentation and the introduction of new species. Maintaining valuable fish species within protected areas can help preserve such species from continued human impacts. However, an understanding of the biology of key species is imperative for the development of management plans to protect and maintain these valued fish fauna.

Within New Zealand, many protected areas, such as State Forests and National Parks, were set aside for their landscape or vegetation values and are generally located at higher altitudes, encompassing headwaters and often mid reaches of aquatic systems under the protective status. In many cases, the lower reaches of streams remain unprotected. In the higher-elevation protected areas, diadromous galaxiids form the native fish species component of biodiversity value. Being diadromous, an obligatory migration to the sea is required to complete the life cycle of these species and therefore maintenance of viable upstream populations of native fish species in many protected areas is reliant upon access to and from the sea.

Of the 17 species of the genus *Galaxias* described in New Zealand (McDowall 2000), the following five are diadromous: inanga (*G. maculatus*), koaro (*G. brevipinnis*), banded kokopu (*G. fasciatus*), giant kokopu (*G. argentus*) and shortjaw kokopu (*G. postvectis*). Their larvae migrate to sea where they spend the winter developing into a juvenile form. During spring each year, mixed-species shoals of these juveniles return to fresh water in search of habitat for growth to adulthood (McDowall 1990). These mixed shoals are collectively termed "whitebait" and comprise a nationwide commercial and recreational whitebait fishery.

Since a large proportion of the lower reaches of rivers and streams in New Zealand are unprotected, migratory pathways from the sea are subject to physical and chemical degradation from human impacts due to urbanisation, industry or farming practices within their catchments. The 1950s through to the late 1990s was an intense period of industrial development in New Zealand, which saw the construction of hydrodams, dairy factories and pulp and paper mills, with effluent from the mills discarded directly into rivers. In addition, after being separated from domestic and industrial sewer systems, untreated urban stormwater runoff is also discharged directly into many New Zealand waterways (Smith 1986).

Recent studies regarding avoidance of highly turbid streams have highlighted concerns regarding the effect of poor water quality on recruitment levels and habitat provision for native diadromous fish species. Boubée *et al.* (1997) demonstrated that increased turbidity elicits avoidance behaviour in both banded kokopu and koaro whitebait, and banded kokopu were found to be the most sensitive of all native fish tested. Field studies by Rowe *et al.* (2000) found that densities of adult banded kokopu were significantly lower in good-quality habitat in the upper reaches of turbid rivers than in similar habitat in clear rivers. It follows that high suspended-sediment loadings, which are a common problem in lowland reaches of New Zealand waterways (Ryan 1991), may modify natural movement and migration patterns of fish.

To meet management objectives for the maintenance of upstream populations of valued diadromous species within protected waters, knowledge of migration cues that draw whitebait, through lowland streams of poor water quality and promote recruitment of juveniles to the good-quality habitat provided by protected areas, would be of considerable benefit. Presently, no migration cue influencing juvenile galaxiid recruitment has been identified. However, Rowe *et al.* (1992) found that koaro whitebait exhibited river-mouth selection that did not correlate to available and accessible upstream habitats. They suggested a pheromone hypothesis for stream selection, proposing that migrating fish choose streams on the basis of the presence of species-specific pheromones. Subsequently, Baker and Montgomery (2001) found an attraction of migratory juvenile galaxiids to conspecific adult pheromones within the laboratory. The use of pheromonal cues may provide a clue to the development of management techniques that assist in maintaining diadromous galaxiid populations within protected waters.

PHEROMONAL ATTRACTION OF GALAXIID WHITEBAIT TO ADULT CONSPECIFICS

Recruitment strategies can be manifested in a variety of ways. Entry of whitebait into coastal rivers or streams is unlikely to be random, because random selection of a tributary with suitable adult habitat, would diminish chances of survival. Therefore, it is suggested that stream selection is an active process in whitebait. This is supported by correlations of whitebait entry to tributaries with physical or environmental variables (McDowall and Eldon 1980). During migration, fish are exposed to a multitude of physical and chemical cues within the water column about available upstream habitats. Physical cues include volume of flow, water depth, clarity and temperature, while dispersed chemical olfactory cues provide information on upstream habitats and faunal inhabitants.

The chemical cue of interest to this paper is adult pheromones. Pheromones released by adult fish signify an established upstream population of conspecifics and therefore accessible habitat for colonisation. The pheromone hypothesis was first suggested by Nordeng (1971, 1977) as a method of natal stream selection by anadromous salmonids. Although it is generally agreed that salmon navigate their way back to their home stream using chemical cues present within the water column, the precise role of population-specific pheromones remains controversial. Currently, Bjerselius *et al.* (2000) provide the only direct behavioural field evidence of pheromones controlling river selection in a migratory fish, where adult sea lampreys (*Petromyzon marinus*) select spawning rivers on the basis of pheromonal odours released by conspecific larvae resident within the stream. Two unique bile acids, petromyzonol sulfate and allocholic acid released by larvae are detected with extreme sensitivity (picomolar detection thresholds) and specificity by the olfactory system of migratory adult fish (Li *et al.* 1995; Li and Sorensen 1997). Given knowledge of the stability of the bile acids, their release rates and modes in larvae, and the detection range of these compounds by adults, Polkinghorne *et al.* (2001) used theoretical extrapolations which suggest that these bile acids are present in sufficient concentrations within lamprey streams to act as a migratory pheromone.

Sea lamprey do not return to a specific site such as their home stream but instead seek suitable habitat for spawning and an established population of conspecifics is a good predictor of suitable habitat. If habitat selection is an active process in galaxiids, then species-specific pheromones would provide a good indicator of suitable and accessible adult habitat.

The three main whitebait species, inanga, banded kokopu and koaro, have been tested for a pheromonal attraction towards adults. Of relevance to this discussion regarding maintenance of viable diadromous populations in higher-elevation areas, are the results for banded kokopu and koaro, because these species are highly selective in habitat. They are adept at climbing falls and will generally seek out first-order streams covered in forest or bush; they penetrate well inland to higher altitudes (McDowall 1990). In contrast, inanga is a lowland species that is less selective in its habitat requirements and generally does not need abundant bush or forest cover. Therefore, in many protected areas inanga are not a key faunal element and this species is not discussed further.

Because of the complexity of testing the pheromone hypothesis in the field, initial experiments have been laboratory based using a two-choice chamber apparatus, focusing on whether juveniles detect and respond to waterborne odours from adult galaxiids. Whitebait were given the choice of moving upstream into clean water or odour-water collected from each of the three main whitebait species, inanga, banded kokopu and koaro (See Baker and Montgomery 2001 for detailed methods). Both banded kokopu and koaro whitebait exhibited a pheromonal attraction towards adult conspecifics (Figs. 1 & 2), with no response shown towards odours from other whitebait species (Baker & Montgomery 2001; Baker and Hicks 2003).

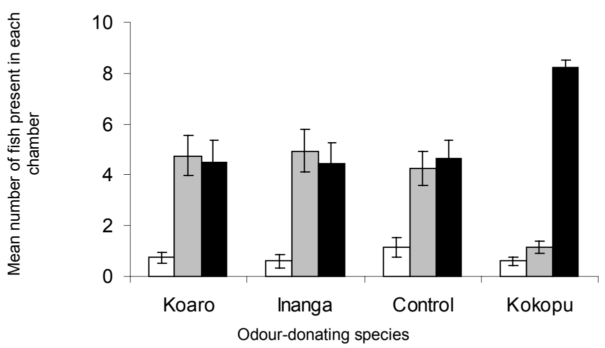

Fig. 1. Mean number of banded kokopu whitebait (*G. fasciatus*) in each chamber given the choice of clean water or odour-water from koaro, inanga or banded kokopu. For control trials no odour-water was added to either upstream chamber. (◎ main chamber, ● non-odour chamber, ● odour chamber. Error bars represent ± one standard error). Adapted from Baker and Montgomery (2001).

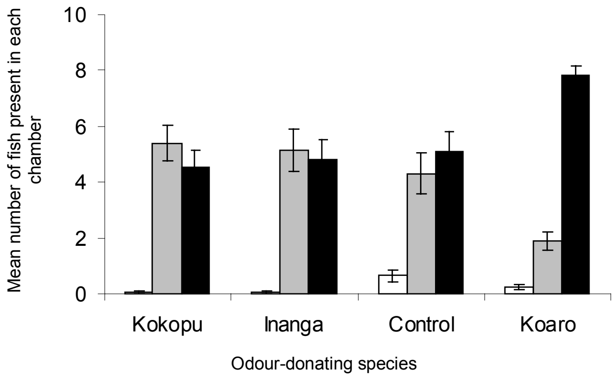

Fig. 2. Mean number of koaro whitebait (*G. brevipinnis*) in each chamber given the choice of clean water or odour-water from banded kokopu, inanga or koaro. For control trials no odour-water was added to either upstream chamber. (◎ main chamber, ● non-odour chamber, ● odour chamber. Error bars represent ± one standard error). Adapted from Baker and Hicks (2003).

Since recruitment of whitebait to adult populations in protected waters is sometimes contingent upon the passage of fish through the lower reaches of streams with undesirable water quality, such as high suspended-sediment loadings, Baker (2003) examined whether the presence of adult pheromones can override a known avoidance response of whitebait to suspended sediments. Boubée *et al.* (1997) found that banded kokopu whitebait exhibited an avoidance response to suspended sediments with a turbidity of 25 NTU, which was also attained in the study by Baker (2003) (Fig. 3).

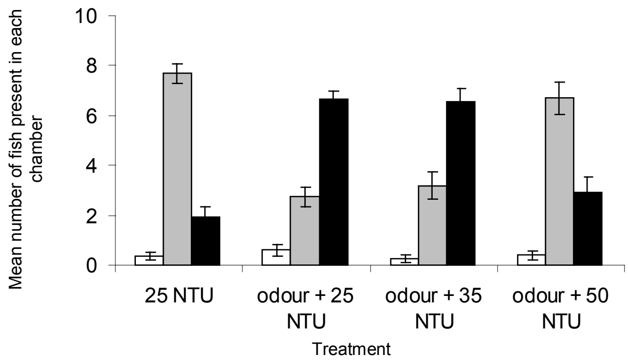

Fig. 3. Mean number of banded kokopu whitebait (*G. fasciatus*) in each chamber given the choice of clean water or water containing adult odours plus suspended sediment with a turbidity of 25, 35 or 50 NTU. Whitebait were also given the choice of clean water or water containing suspended sediment with a turbidity of 25 NTU. (◎ main chamber, ● clean water chamber, ● odour + suspended sediment chamber. Error bars represent ± one standard error). Adapted from Baker (2003).

The addition of adult pheromones to suspended sediment with turbidities of either 25 or 35 NTU elicited an attraction of whitebait to the odour-plus-suspended-sediment chamber. At a loading of 50 NTU, Boubée and colleagues found a stronger avoidance with a further decrease in the number of fish entering the suspended-sediment chamber compared with a loading of 25 NTU. In contrast, Baker (2003) found that with the addition of adult pheromones higher numbers of whitebait entered the odour-plus-suspended-sediment chamber than when sediment with a turbidity of 25 NTU was presented alone.

These results collectively strengthen the hypothesis that adult pheromones play a role in stream selection by koaro and banded kokopu whitebait. Not only can whitebait discriminate odours from adult conspecifics, but they are attracted to waters containing odours released by their adult counterparts and this attraction can override an avoidance reaction to suspended sediments.

ADULT PHEROMONES AND AQUATIC PROTECTED AREAS

By default rather than by design, one of the roles of the many terrestrial protected areas in New Zealand is to preserve fish fauna and protect fish populations from human impacts. Management strategies currently encompass the maintenance and provision of water quality, flow regime, nutrient sources, habitat structure and barrier-free access; however, the management of diadromous fish populations relies not only on the provision of quality adult habitat but also on consistent recruitment of juveniles. Successful recruitment of juvenile galaxiids can sometimes be contingent upon migration through unprotected and degraded pathways with undesirable water quality. Migratory cues, such as pheromones, that positively influence stream selection of whitebait, can be incorporated as tools in mitigation strategies for the maintenance of diadromous fish populations in protected waters.

Positive recruitment of whitebait in the Nukumea Stream in Orewa, north of Auckland, provides an example in which adult pheromones may be influencing conspecific juvenile recruitment through undesirable lowland waters. The Nukumea is a small stream adjacent to urban Auckland with relatively unmodified catchments. An abundant and diverse fish assemblage has been recorded within the Nukumea catchment, which contains eight native diadromous fish species, including banded kokopu (Boubée 2000). The upper reaches of the stream contain excellent habitat for banded kokopu due to good instream cover provided by woody debris and plant material, root mats and undercut banks (Boothroyd *et al.* 1999). Instream habitat is represented mostly by pools, and the stream is enclosed with abundant overhanging riparian cover. Accordingly, the densities of banded kokopu within the stream are high, with up to 5 fish per 10 m^2 (Boubée 2000). Not only are fish densities high, but the size-class data indicate that juvenile recruitment does not fluctuate and remains consistent among years. Fish surveys within the Nukumea stream reveal a wide range of size classes, from whitebait size of 25 mm up to an adult size of 170 mm (Boubée 2000). Fish lengths were normally distributed with a mode of 60 mm. In contrast to its upper reaches, the mouth and lower reaches of the Nukumea Stream contain a reasonably high suspended-sediment loading, with turbidities at or above 25 NTU during normal flows (Boothroyd *et al.* 1999). As previously stated, banded kokopu whitebait have been shown to avoid suspended sediment with turbidities of 25 NTU or higher (Boubée 1997), which has also been supported by field studies (Rowe *et al.* 2000). However, banded kokopu whitebait are consistently being drawn through the lower reaches of this stream and recruiting to the good-quality habitat present in the upper reaches, thereby maintaining the high densities of banded kokopu within this stream. It is reasonable to infer that adult pheromones may be responsible for this high level of recruitment. If adult pheromones can influence stream selection in whitebait, then enhancing the densities of adult fish in protected waterways could be a useful management tool for ensuring annual recruitment of whitebait to protected populations and maintaining biodiversity.

Within urban environments, many streams harbour the effects of intensive land modification, with reduced fish densities and low diversity. Urban stream management has recently shifted towards stream restoration and protection, in an attempt to recreate a healthy ecosystem with high biological values. In order to re-establish good-quality habitat in degraded streams, flow regime, water quality and riparian vegetation must all be restored, or at least improved. Many published studies report increases in fish densities after restoration of habitat (Van Zyll de Jong *et al.* 1997; Kelly and Bracken 1998; Scruton *et al.* 1998; Jeffree 2001). However, an increase in fish diversity, with new species inhabiting restored areas, is not always seen in the short term. With respect to diadromous fish species, sometimes the provision of suitable habitat may not be enough to influence juvenile recruitment. If adult pheromones are used as a cue in stream selection by whitebait, then the seeding of adult galaxiid populations may draw juveniles into newly restored and protected waterways, hastening the creation of self-supporting fish populations.

Recently, habitat enhancement of Christchurch City urban streams has been undertaken to investigate the effect of restored habitat quality on biological communities. Ecological surveys were carried out in 1995 prior to stream restoration and repeated five years after enhancement in 2000 (NIWA unpublished results). Sections of five streams were restored through riparian planting or a combination of channel naturalisation and riparian planting, with adjacent non-enhanced sites surveyed as controls. Baseline fish communities had low diversity, consisting mainly of a combination of diadromous shortfinned eel (*Anguilla australis*), longfinned eel (*A. dieffenbachii*), common bully (*Gobiomorphus cotidianus*) and giant bully (*G. gobioides*), plus the non-migratory upland bully (*G. breviceps*). Surveys in 2000 showed an increase in fish densities within restored sections of streams with a doubling in fish biomass compared with control sections. However, with the exception of the presence of a few inanga in one enhanced stream section, there was no increase in diversity of fish communities over the five-year period. Banded kokopu are prevalent in streams on Banks Peninsula, a volcanic landform just south of Christchurch, signifying the presence of whitebait at sea, but adult banded kokopu have been absent from Christchurch urban streams for many years (NIWA unpublished data; McDowall 2000). Plans are in motion to stock restored streams with banded kokopu populations in the expectation that the presence of adult fish will attract whitebait back into Christchurch urban streams.

Such measures not only potentially draw whitebait into such habitat but in themselves expand the current distribution of fish species and enhance the biodiversity of protected waters. Many inland waters contain suitable habitat for galaxiid species, yet adult populations are still absent. For example, surveys of freshwater fish within the tributaries of the Tarawera River in 1998 and 2001 found an abundance of good-quality koaro habitat, yet no adults were found (Young and Griffiths 2000; Park 2001). Koaro were last recorded in the Tarawera River catchment in 1994 and found only in the Mangaone Stream. Since then, adult fish have been absent and no koaro whitebait have been found entering the river (Rowe *et al.* 1992; Young 2000). Other Bay of Plenty rivers adjacent to the Tarawera have low numbers of koaro adults within tributaries and low numbers of koaro whitebait were found entering such rivers (Rowe *et al.* 1992; Young 2000). The one exception is the Motu River, where many tributaries are abound in koaro populations (Rowe 1981), and where koaro whitebait constituted over 70% of the whitebait catch entering the Motu River – significantly higher than any other Bay of Plenty River (Rowe *et al.* 1992). In this situation, the translocation and stocking of koaro populations into tributaries of the Tarawera River, or other Bay of Plenty rivers, may provide the necessary cue to draw in juvenile recruits to the suitable and accessible habitat provided by such rivers.

CONCLUSION

The positive response to conspecific adult pheromones exhibited by banded kokopu and koaro in laboratory tests is supported by distributional evidence from field studies and suggests that pheromones may be used by banded kokopu and koaro whitebait as a migratory mechanism for effective stream and habitat selection. The use of adult pheromones could be incorporated as a management tool into management strategies to maintain the diversity and high densities of diadromous galaxiids within protected waters. This could take the form of enhancement or seeding of adult populations where they are absent or in low densities, to encourage consistent juvenile recruitment.

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ROLE OF AQUATIC PROTECTED AREAS IN THE CONSERVATION OF AQUATIC ECO-SYSTEMS: SRI LANKAN EXPERIENCE

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Abstract

Lagoons and estuaries are important coastal ecosystems where human interventions can cause changes that drastically alter the appearance and the resource profile of the system. The communities that depend on these resources seek government assistance to reverse or arrest these changes in order to enjoy the same benefits that they traditionally enjoyed. Is this sustainable and cost effective or is it wise to get their livelihood and consumption patterns changed to accommodate the natural changes?

In Sri Lanka during the pre-colonial administrative period, community structures were in place for sustainable resource exploitation and these were implemented and monitored by demi-officials selected or elected with community acceptance. This system was readily accepted by resource users, because there was a sense of ownership and the possibility of punitive actions against violations. Later, this was changed towards command and control management. However it did not fulfil the aspirations of resource users and managers. The Coast Conservation Department in realizing this problem introduced the Special Area Management (SAM) concept in the early 1990s, expecting effective and efficient resource conservation through enlightened community participation.

The case of Kalametiya, one of several SAM sites funded under an Asian Development Bank (ADB) Coastal Resources Management Project, demonstrates the adverse effects of external pressures and threats on aquatic protected area (APA), posing the necessity for long-term protection of the system. This paper discusses the role of APAs and stakeholders for successful resource management.

Keywords: APA, Sri Lanka, special area management, resource management

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INTRODUCTION

Coastal wetlands lagoons and estuaries, especially in the tropics, are amongst the most productive areas in the world and are considered to be important environmental units at high risk from pollution, over exploitation, habitat destruction and other anthropogenic activities. The need to manage them in order to ensure their sustainability is well accepted. The economies of some of the South-East Asian Nations depend heavily on natural resources through activities such as fishing, aquaculture, mining and salt making. In addition, there are other activities that are more diverse or in transition, include coastal activities, such as tourism, shipping and industrialization, which also affect the biological heritage of the coast. Some coastal wetlands in Sri Lanka are also used as anchorages for fishing boats, flood retention areas and as fish-landing centres. Lagoons and estuaries are subject to geological changes and undergo drastic changes in appearance and resource profile in the long term. These changes present socio-economic and environmental problems to the user community. This process is accelerated by human activities carried out in the name of development without due consideration of the environmental concerns. The Kalametiya coastal wetland, on the south coast of the island about 25 km east of Tangalla town, is a case in point.

Kalametiya Lagoon (Fig. 1) is at the tail end of the Kachchigal Ara basin and is bordered by the Urubokka Oya to the west and Walawe river basin to the North and East. The tributary known as Buwely Ara joins the Kachchigal Ara from the west bank. The basin has an annual precipitation of some 250 million cubic metres (Anon. 1995).

The lagoon covers an area of 750 ha and is surrounded by fringes of marsh vegetation and mangroves stands; further away, the lands are mainly classified as chena or paddy fields. Along the coast, a low and narrow ridge of sand dunes separates the lagoon from the sea. The ecosystem is rich in bio-diversity and is environmentally significant. In view of this, the Governor of Ceylon declared it as a Wild life Sanctuary under the *Flora and Fauna Protection Ordinance 1938* (FFPO). This declaration was degazetted in 1946

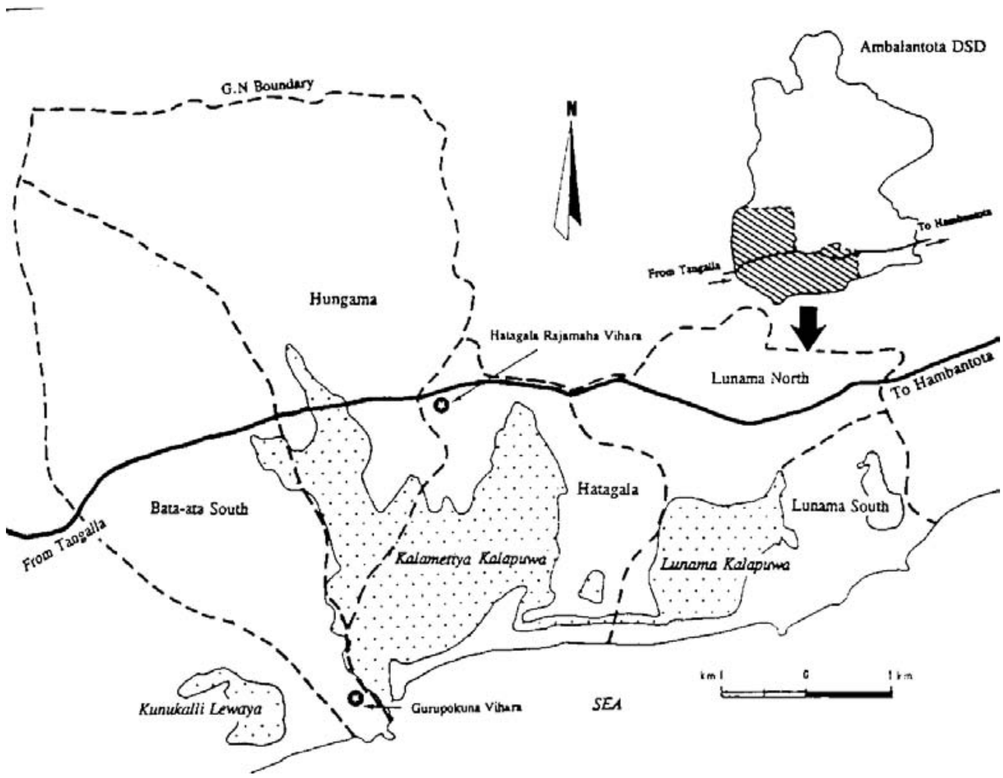

Fig. 1. Location of Kalametiya Lagoon (Kalapuwa).

in response to objections from local residents (Scott 1989). After a strong campaign by conservation groups, the area was re-declared as a sanctuary in 1984 under the FFPO.

Its significance for conservation was further emphasized by its inclusion in the Directory of Asian Wetlands (Site No. 28) (Scott 1989). In the past, the wetland was well connected to the sea by periodical openings through a sand bar, and the required volume of fresh water to maintain the salinity favourable for shrimp, crab and many marine species had been provided by a small stream, Kachchigal Ara, which since the implementation of irrigation interventions has become a major river (see Fig. 4). The temporal context of all of this is not clear, as is the present status.

The Udawalawe south bank was developed and trans-basin connections were made to the Kachchigal Ara in the 1960s. As a result, paddy cultivation within and outside the catchment has greatly expanded. Some 5000 ha of paddy lands were added to the existing paddy lands upstream. This has led to a greatly increased influx of fresh water into the lagoon. This, in turn, aggravated the flood menace in the area. The paddy fields at Hatagala and Lunama became periodically inundated. To discharge this flood water, a canal was constructed to connect the lagoon with the Kachchigal Ara. However, the tidal action was not strong enough to reverse the flow and as a result the extent of salt-water exchange into the lagoon decreased substantially and the lagoon became a fresh-water body. This has created social, economic and environmental problems (Fig. 2).

With the decrease in salinity, the resource profile of the lagoon was completely changed. High-value fish species such as shrimp, crab and marine species that were in high demand disappeared. Fresh-water fish species, e.g. catla, carp and tilapia, have become dominant. The number of species as well as the number of fish in the lagoon dropped drastically and resulted in a decrease of bio-diversity and also a collapse of the lagoon fishery. This has worsened the economic condition of the fishing community that was dependent on the lagoon resources.

Taking all these facts into account, the Department of Coast Conservation (CCD) included Kalametiya in their Special Area Management Programme (SAMP). The Coastal Resources Management Project (CRMP) funded by the ADB has taken steps to bring this important coastal wetland under effective natural resource management. The objective was to sustain natural resources and prevent environmental degradation in Kalametiya Special Area (KSA) while improving the socio-economic status of the local communities, which is moderate and poor. About 61% of the families receive either food stamps or social security benefits from the government. This paper discusses the role of aquatic protected areas (APAs) and stakeholders for successful resource management in the coastal wetlands of the island, citing the Kalametiya case as an example.

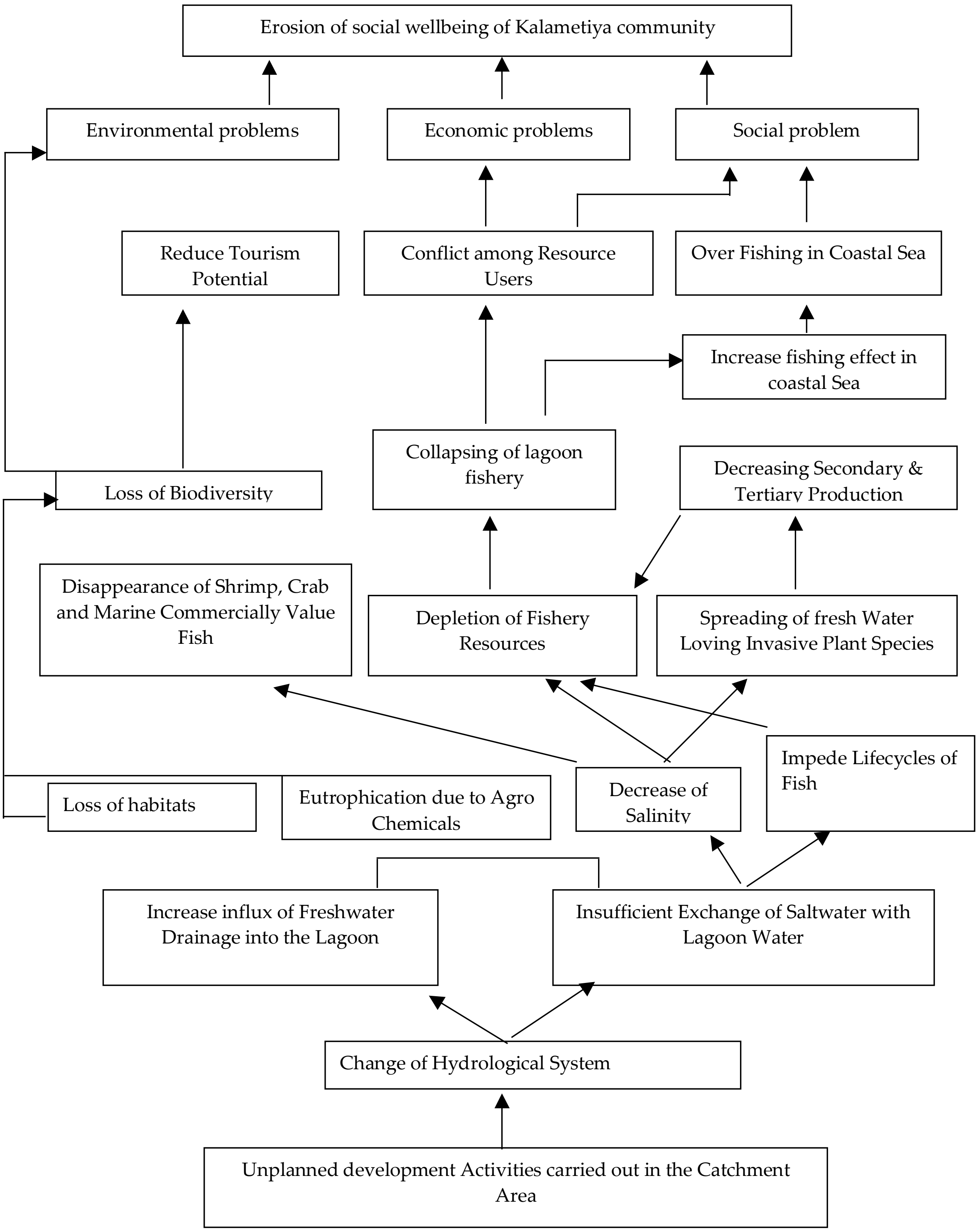

Fig. 2. Change of the hydrological pattern due to unsustainable development has brought the Kalametiya aquatic ecosystem under heavy pressure.

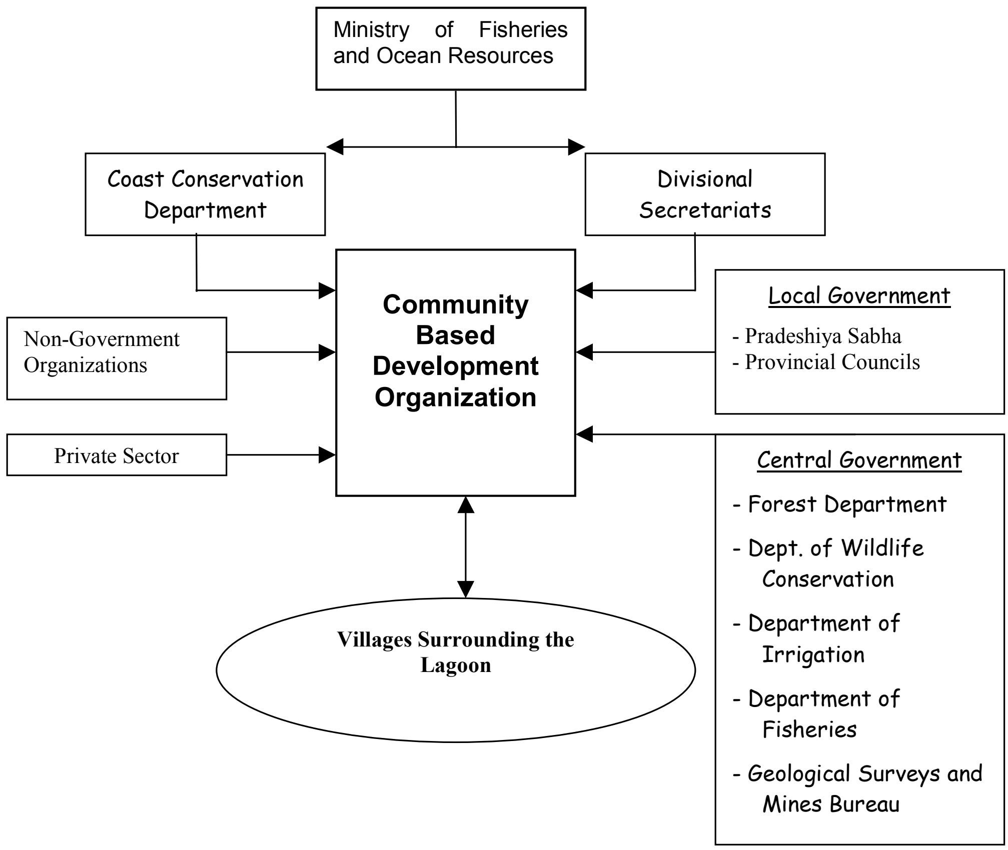

Fig. 3. Institutional mechanism to strengthen inter-agency coordination and cooperation.

METHODS

A Field Implementation Unit of the CRMP was established in Tangalla in October 2001 and a massive programme was launched to make the local community and the other stakeholders aware of the measures proposed for Kalametiya under CRMP assistance. A further objective of the project was the formation of a community-based organisation that would be directly involved in management of the resources. A Community Environment Committee was set up in each village bordering the lagoon, and based on these Committees, the Kalametiya Community Development Foundation was set up in early January 2002. Since the aim is community participation and co-management, the community-based organization has a vital role to play in planning, implementing and monitoring the activities carried out under the project.

The government departments, private sector, provincial administration and the NGOs of the area too have important roles to play for the success of the Kalametiya Special Area Management effort. To strengthen the coordination and cooperation of the stakeholders (Fig. 3), the Kalametiya Community Coordinating Committee (KCCC) was established. The KCCC meets regularly under the chairmanship of the Divisional Secretary Ambalantota. The CCD at the central level, and the Divisional Secretariat at the provincial level, are to assist the Kalametiya Community Development Foundation (KCDF) in achieving a smooth operation. The Ministry of Fisheries and Ocean Resources provides further support when policy reforms are needed, by steering such reforms through central government channels.

The data and information in respect of Kalametiya were collected through a series of meetings held with the community, religious leaders, local heads of departments, private sector and NGOs of the area. In addition, field visits were made to the KSA including the lagoon. Brain-storming sessions were then held with subject specialists and a series of Participatory Rural Appraisal were conducted in villages surrounding the lagoon. The resultant data and information were analysed for problems, issues and possible solutions. On the basis of these findings, short-term, medium-term and long-term activities to be carried out in Kalametiya were identified in order to sustain the resources and conservation of biodiversity, whilst enhancing the socio-economic standing of the community. The KCCC meets once a month. Progress is reviewed periodically to strengthen the weak areas, identify opportunities and remove constraints faced during the implementation of the project activities.

The community plays the most important role in this exercise through participation in the KCCC. Such participation helps to develop self-confidence and establish an identity vital for active participation in planning, implementing and monitoring the project.

RESULTS AND DISCUSSIONS

Kalametiya eco-system was one of the most productive lagoons on the south coast three to four decades ago with a well-established fishery in the lagoon. Kalametiya was famous for its shrimp fishery before the 1960s. It also supported a multi gear and multi species fishery. Before the 1970s, the production of the shrimp fishery was so high that the catch had to be disposed by cane baskets, not by kilograms or pounds. During that period there were more than 300 fishermen actively engaged in fishing in Kalametiya, whereas today there are 20-30 fishermen. With great difficulty and in a full day's fishing, they catch a small quantity that is worth about Rs 100. This is not enough to meet even their day-to-day expenses.

Although still multi-gear, it has turned from a well-established commercial fishery into a low subsistence fishery. The catch is low and comprises few species. The high-value species such as shrimp and crab have disappeared from the lagoon as a result of the decrease in salinity. With the development of the Walawe Right Bank Canal and the Udawalawe Right Bank Canal, there has been a gross change to the upstream hydrological pattern and this has had a major adverse impact on Kalametiya: the original saline-to-brackish lagoonal complex has become a freshwater marsh, thereby changing the resource profile and threatening biodiversity and the livelihood of the local community.

Less popular low-value fresh water fish species, e.g. *Oreochromis*, carp and catla, are now dominant in the lagoon with a lower overall population density. The number of fish as well as the number of species has substantially dropped and in turn resulted in a decrease of faunal diversity, especially of birds in the ecosystem, due to scarcity of food in both quantity and quality.

The lagoon is eutrophic as a result of an inflow of organic waste and nutrient-rich fresh water from agricultural lands upstream where inorganic agrochemicals are used on a lrge scale. This has resulted in the spreading of aquatic weeds and the occurrence of fresh water macrophytes. Some 75% of the lagoon is now covered with *Typha* reeds and sedges (Anon. 1995). Oxygen depletion of the lagoon due to the excessive cover by waterweeds hampers the secondary and tertiary aquatic production in the wetland. The lagoon is subject to heavy sedimentation by silt-rich drainage water from upstream where agriculture practices do not adopt adequate soil conservation measures: this has converted more than 70% of the lagoon area to a marsh. Environmental services including spawning and feeding functions for many local and migratory bird species and finfish and shellfish species have been lost from the ecosystem.

The International Waterfowl and Wetland Research Bureau, in cooperation with the Ceylon Bird Club, had recorded 151 bird species in the Kalametiya lagoon of which 54 were migrants, especially herons, egrets and spoonbills (Anon. 1995). Many rails, coots and jacanas could be found in the lush reeds and marsh vegetation. Waterfowl regularly numbered up to 20,000 in the past, and the endemic Sri Lankan jungle fowl were found in the lagoon together with eight rare species. All these bird species are under serious threat due to the inadequate food stock in the lagoon. Most of the bird species that migrated to the lagoon in the past do not visit now and the overall number of birds that regularly visit the lagoon has also reduced drastically. The barking deer and Sambur deer have recently disappeared from the area. Spotted deer are sighted occasionally but not as frequently as in the past, according to the local communities.

The coastal wetlands of South-East Asia are some of the richest ecologically. They are characterized by diverse ecosystems, a warm tropical climate and ample rainfall. They are enriched with nutrients from land that enable the wetlands to support critical terrestrial and aquatic habitats which comprise unique coastal ecosystems containing a valuable collection of natural resource systems. For some of their goods (e.g. fish) and services (e.g. tourism) from the coastal wetlands, prices are established, whereas for other goods (e.g. seagrass beds) and services (e.g. nesting ground of birds), no effective and enforceable property rights have been established.

In the absence of effective property rights and their enforcement, markets often fail. This failure results in externalities or spill-over effects, since some benefits or costs associated with production or consumption are external to the one who undertakes it. Consequently, the person who produces the externality does not pay for it but it affects others. In the case of negative externality, the full cost of the activity is not considered in decisions and it is continued beyond the socially desirable level. Policy failures as well as market failures are equally responsible for externalities, which adversely affect coastal resources.

Prior to the completion of the Udawalawe Dam in 1967, the lagoon used to be fed by a combined influx of rainwater, runoff from the Kachchigal Ara catchment drainage water from upstream irrigation schemes and seepage of seawater through the dune zone and the lagoon outlet in the Kalametiya Lagoon. In particular the Walawe Right Bank Canal, constructed in 1887 and originating at the Liyangastota anicut and joining the Kachchigal Ara at Athbatuwa, contributed to the fresh water inflow. Drainage inflow was also received from the Miniethiliya and Lunama canals. After the completion of the Udawalawe scheme, the upstream hydrological pattern changed markedly. Branch canals originating from Udawalawe Right Bank Canal have been constructed and this supplies vast tracks of land in the Kachchigal Ara catchment with irrigation water. The water flow of the Ara was increased largely by the irrigation waters of the Mamadala and Gurugadalla branch canals coming from the Udawalawa Left Bank. At Gajamangama and Bata Ata two other branch canals feed the lands of Kachchigal Ara Right Bank and the drainage water flows directly into the lagoon (Fig. 4).

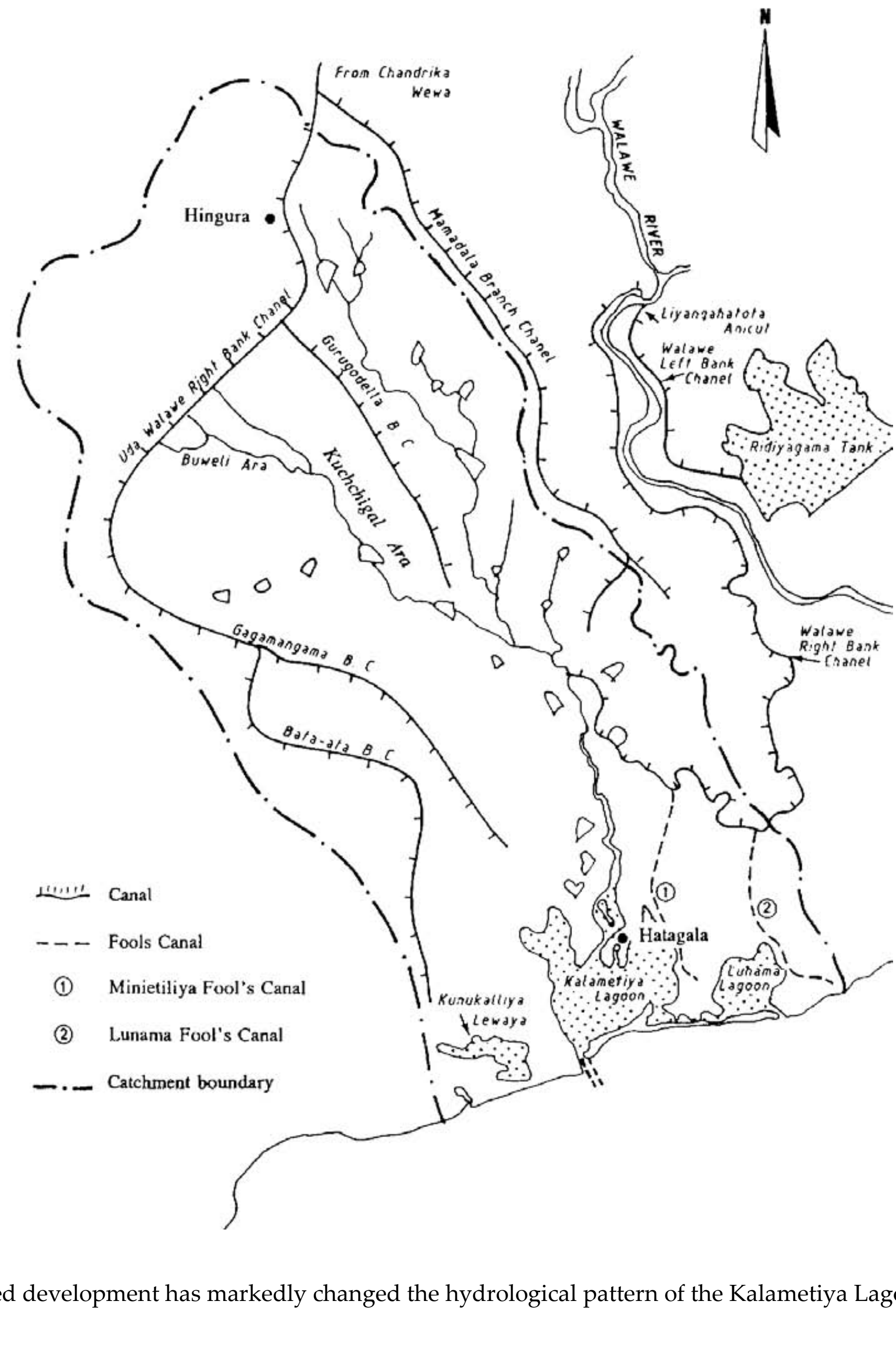

Fig. 4. Unplanned development has markedly changed the hydrological pattern of the Kalametiya Lagoon.

As a result of the influx of a large volume of fresh water into the lagoon since 1967, previously cultivated paddy lands in the northern part of the lagoon became inundated and were abandoned. To divert excess water to the lands deprived of fresh water in the Hiwalgala area closer to lagoon and also to ensure speedy discharge of water into the sea to reduce the flooding, a new canal was constructed from Minietiliya canal to the sea, through the lagoon. In the late 1960s an artificial sea outlet was constructed. This outlet remains open throughout the year and allows a continuous flow of water into the sea. However, the tidal action is insufficient to reverse the flow.

The continuous inflow of freshwater into the lagoon and outflow to the sea through the outlet restricts tidal inflows and appears to maintain the low salinity level (0-2.2%) in the lagoon. As a result, freshwater-loving submergent plants, e.g. *Pistia, Salvinia, Ipomea, Eichhornia and Najas marina,* have invaded the lagoon. A *Sonneratia* species, introduced in the early 1950s through only three plants, has spread rapidly over the lagoon, resulting in a large mangrove forest.

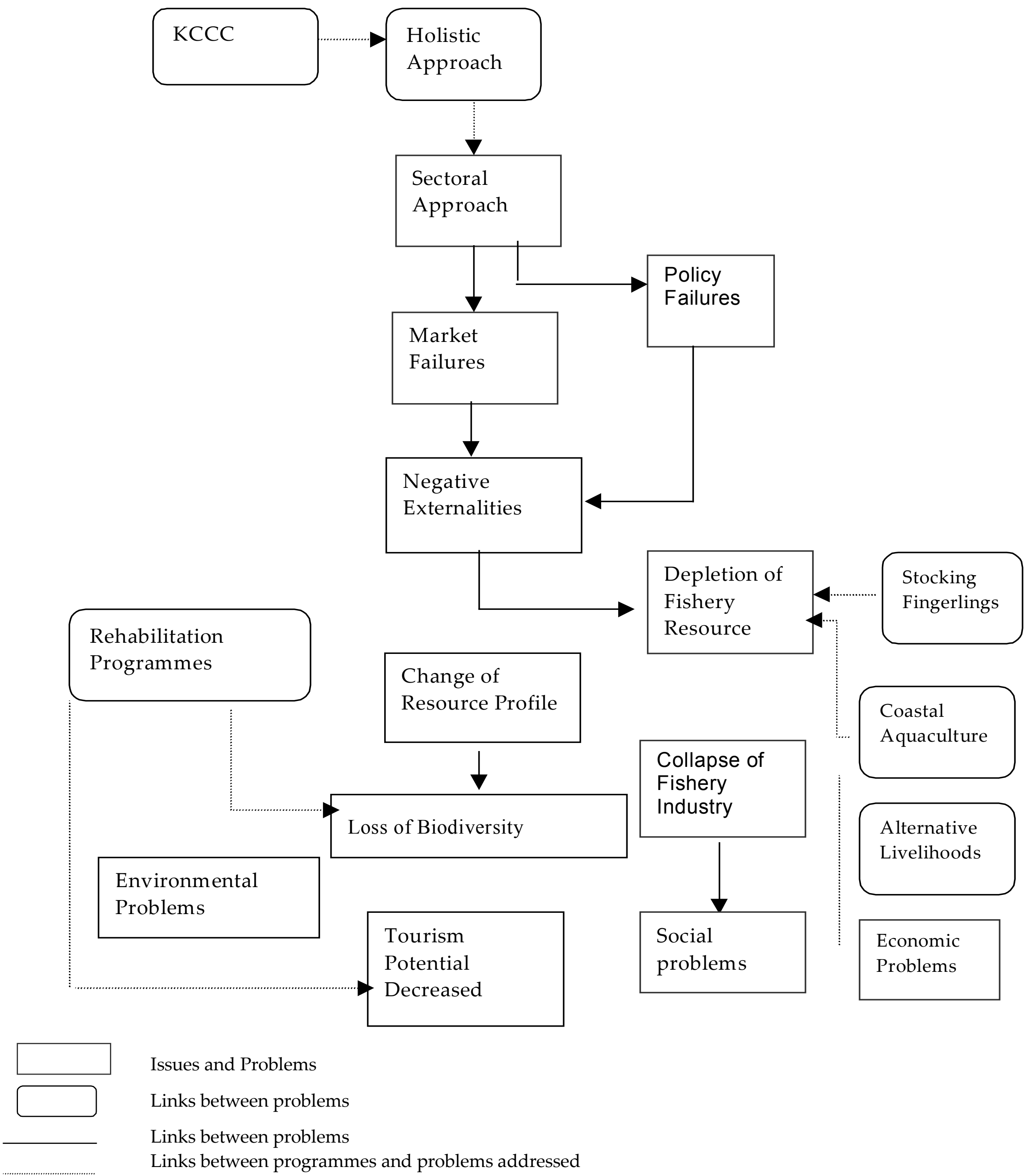

Fig. 5. Integrated approach of the Kalametiya Coastal Area Management Plan.

Previously there were approximately 100 tanks in the catchment to meet the water requirement of paddy cultivation. This system functioned as a water storage and controlled the freshwater inflow into the lagoon. With the commissioning of the Walawe Right Bank Canal and Udawalawe Right Bank Canal, tank maintenance ceased and many tanks were abandoned or converted into paddy lands. Heavy rains in 1969 damaged the irrigation system and largely reduced the flood retention capacity of the basin. After the commissioning of Udawalawe reservoir in 1969, some 5000 ha of new paddy fields were created and the consequent increase in freshwater inflow led to a loss of the brackish-water condition of the lagoon that had favoured valuable shrimp production ground.

As tidal influence ceased and agrochemicals accumulated in the lagoon, the resultant eutrophication led to the spread of aquatic weeds, the occurrence of fresh water macrophytes and consequent oxygen depletion. More than 60% of the lagoon is now covered with *Typha* reeds and sedges. This, together with desalinisation, accounted for depletion in the fishery resource of the lagoon until fishing is now carried out only at a subsistence level (de Silva 1983; Anon. 1995).

It is generally recognized that the coastal ecosystems are best managed from a holistic perspective in which all components are assumed to be interdependent. Although prescribed projects pass through Environmental Impact Assessment, not all projects are subjected to environmental screening. Therefore no Department in the island addresses the environmental problems in a holistic perspective. Administrative jurisdictions of these Departments are highly protective of their core responsibilities. The institutional mechanism (Fig. 3) of the KCCC now in Kalametiya is a better forum for planners, policy makers and administrators to develop a project by addressing the environmental problems in a holistic perspective, because the KCCC is attended by all key players in natural resource management: resource users, resource managers and the resource guardians.

The resource users, who prefer to retain the benefits that they or their forefathers enjoyed in the past, request the government to reverse these changes. Although it is possible to do so, the problem is the cost involved and whether it is cost effective. The whole problem in Kalametiya is centred on the river Kachchigal Ara which brings a large volume of fresh water from irrigated agriculture fields to the lagoon. It can be diverted from the lagoon. Such a solution will not be cost effective. The better alternative is to change their consumption patterns and livelihood styles of the community to suit the changed circumstances. Such a solution would have to be backed by a campaign r to change the attitudes of the community and their behaviour. The CRMP Tangalla is engaged in this exercise at the moment (Fig. 5). It is too early to draw conclusions, but in view of achievements to date it appears that there is reason to be optimistic.

CONCLUSIONS

The case presented demonstrates that sector-based economic development in coastal areas leads to market and policy failures when development is not integrated. Planning interventions are essential to correct these failures and reflect resource scarcity in decisions regarding resource-use. Guidance for appropriate policy interventions is best achieved through collaborative, integrated approaches that address key environmental, economic and institutional factors influencing progress towards sustainable development. To be effective, management plans should be integrated with development plans and implemented in a coordinated fashion.

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IMPORTANCE OF ESTABLISHING BOWIE SEAMOUNT AS AN EXPERIMENTAL RESEARCH AREA

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Abstract

Bowie Seamount is a discrete ecosystem, 180 km west of the Queen Charlotte Islands. Many of the fishes found in the waters over the seamount also occur in coastal ecosystems. However, the trophic system at the seamount is simpler than the typical coastal ecosystems because of the apparent diminished presence of the small-pelagic community on the seamount relative to the number of species at the highest trophic levels. There are fisheries on the seamount, but there are no assessments of sustainable catch for these fisheries. In fact, past management for some species has not included the catches as part of the total specific allowable catch, apparently because the fish were assumed to be surplus to the coastal population. New legislation in Canada, however, would indicate that an ecosystem-based approach is now an appropriate way to manage these species. Not only should there be an assessment of the acceptable catch of target species, there also should be an assessment of the impact of the removal of these fish on the dynamics of the associated species. The Bowie Seamount ecosystem should be protected, and the protection should allow for experimentation that will improve our understanding of the impacts of fishing on both target and associated species. An experimental ecosystem at Bowie Seamount can also be used to establish the processes and policies needed to implement an ecosystem-based management approach in the coastal ecosystems.

Keywords: Seamounts, fisheries, ecosytem based management, research area

INTRODUCTION

Single-species management was the first step in the stewardship of our aquatic resources. Incorporating ecosystem considerations in the management of fisheries is now recognized as a necessary next step in management (Government of Canada 1996; FRCC 1998; NMFS 1999). Moving towards an ecosystem-based management approach is difficult because managers and scientists have few relevant studies to guide them into the new territory of multi-species assessment. One approach to moving away from single-species management is to experiment with new approaches and designate discrete ecosystems as sites for protection and study.

We propose that an experimental approach to ecosystem-based management be developed for Bowie Seamount. The approach would also be experimental in policy, as it would facilitate the development of new management approaches such as managing the impact of fishing on non-target species. We propose that Bowie Seamount can provide the prototype experimental ecosystem to examine how fishing one species impacts on the dynamics of associated species. In this paper we show that it is important to manage the fisheries at Bowie Seamount in a manner that uses past and future information to understand how to develop ecosystem-based approaches. As we learn how to measure these impacts in an area that is discrete, we can also learn how to transfer this knowledge to coastal ecosystems.

BOWIE SEAMOUNT

Bowie Seamount (53°18'N, 135°39'W) is a relatively discrete marine ecosystem because of its 180 km separation from the closest coastal ecosystems of the Queen Charlotte Islands (Fig. 1). Bowie Seamount is one of the shallowest seamounts in the Northeast Pacific, rising from 3100 m to 25 m below the surface (Dower and Fee 1999). The area of seamount that rises to within 1000 m of the surface is approximately 120 km^2 and is designated as the habitat area for fish in this report. The fishes at Bowie Seamount, including Pacific halibut (*Hippoglossus stenolepis*), sablefish (*Anoplopoma fimbria*), 20 species of rockfish, and 29 other species of fish, are also common in coastal ecosystems (Dower and Fee 1999). Rockfish, sablefish and Pacific halibut have been fished commercially, but assessments of acceptable catch have not been made and there has not been an evaluation of the impacts of this fishing. Our review of these fisheries indicates a need for improved catch and biological data. We show that it is necessary to begin to include information on diets as a routine measure of fishing impacts.

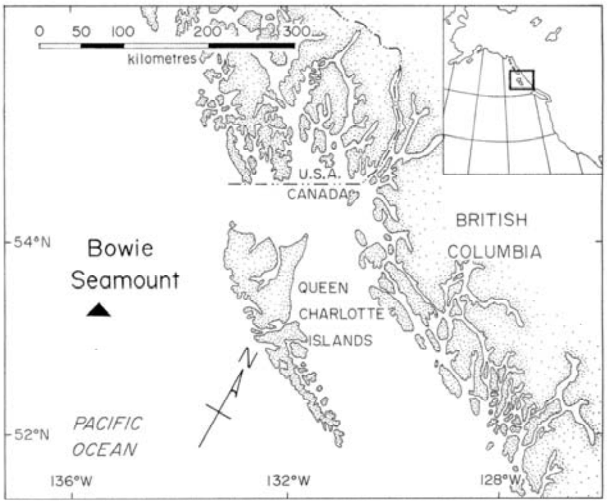

Fig. 1. West coast of Canada showing the location of Bowie Seamount 180 km south-west of the Queen Charlotte Islands.

Fisheries at Bowie Seamount

Pacific halibut

The halibut fishery at Bowie Seamount may have started decades ago according to oral reports from fishermen; however, there are no records of these early removals. There also are no specific assessments of total biomass of Pacific halibut at the seamount. We used one report of a fishing trip in 1990, in which 16,800 kg were caught in 48 h, to describe the possible population of Pacific halibut on the seamount. During this trip, the vessel fished 8 skates to a string with 80 hooks to a skate. The catch was 450 kg/skate. All Pacific halibut were large, ranging from 27 kg to 118 kg with an average size of 45 kg. This was greater than the average size of halibut that are typically caught in the commercial fishery in the Canadian zone. For example, in 1998 the average size and age of Pacific halibut in the Canadian zone was 10 kg and 11.8 years old (Forsberg 2001). This suggests that most Pacific halibut caught at Bowie Seamount in 1990 were older than 12 years.

We attempted to estimate the biomass in 1990 by comparing the habitat area and catch rates at Bowie Seamount with habitat area and catch rates in the coastal zone. We recognize that this is an approximate estimate and that abundances at the seamount may have fluctuated during the 1990s. However, even an approximate estimate of biomass of each of the major species on the seamount will allow an assessment of the impacts of fishing on the community of fishes.

In 1990, the biomass of commercially exploitable halibut in the Canadian zone was 24,000 t (Clark and Hare 2000). The International Pacific Halibut Commission has estimated that the habitat area suitable for halibut in the Canadian zone could be approximately 96,000 km^2 (unpublished estimate of habitat area). This indicates that the biomass of halibut in the coastal area in 1990 was approximately 0.25 t/km^2. The average catch rate in the Canadian zone in 1990 was 79 kg/skate (Clark and Hare 2000). The catch rate at Bowie Seamount in 1990, at 450 kg/skate, was 6 times the catch rate in the coastal areas. This relationship was used to estimate that the biomass on the seamount was 6 times the coastal biomass per unit area or 1.5 t/km^2, i.e. a total of 180 t in the habitat area of 120 km^2.

Sablefish

The sablefish fishery off Canada's coast expanded from a small Canadian fishery to a larger international fishery when the Japanese began fishing in 1964 (McFarlane and Beamish 1983). It is not known whether the Japanese fishery occurred on Bowie Seamount, although there is evidence of a Japanese fishery on Cobb Seamount 500 km south-west of Vancouver Island. The Japanese catch reached a maximum of 6506 t in 1975 (McFarlane and Beamish 1983), compared with recent annual catches of about 4000 t (Fig. 2). The Japanese fishery terminated after Canada extended its fishing jurisdiction in 1977.

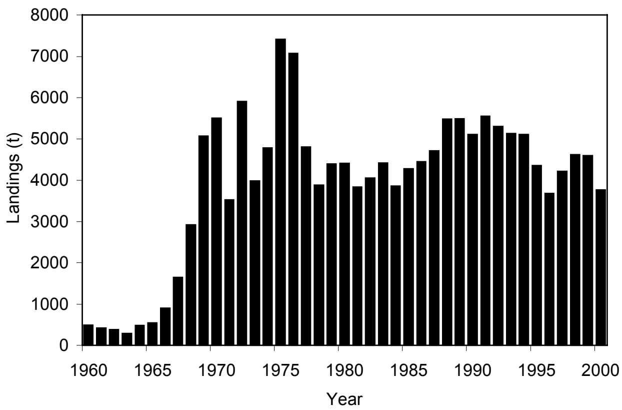

Fig. 2. Total catch (t) of sablefish from 1960 to 2000 off Canada's west coast.

A history of a Canadian fishery for sablefish on Bowie Seamount can be documented from 1987 to 2000 (Table 1). Canadian sablefish catches from the seamount are not counted in the total annual allowable catch or in the individual quotas owned by fishermen (DFO 2000). Thus, a fishery on the

Table 1. Catch of sablefish (*Anoplopoma fimbria*) at Bowie Seamount and total commercial catch in British Columbia.

Year	Catch at Bowie Seamount (t)[a]	Total Canadian Landings (t)[a,b]
1987	88.7	4717.7
1988	139.7	5477.2
1989	112.3	5488.1
1990	117.5	5103.6
1991	353.4	5549.2
1992	203.5	5305.7
1993	26.1	5132.1
1994	37.2	5100.3
1995	42.1	4359.1
1996	100.9	3677.6
1997	51.1	4216.0
1998	12.1	4611.8
1999	87.1	4598.0
2000	79.8	3767.6

[a] Data from DFO groundfish catch database or from log books; 1991 and 1992 have been corrected to exclude catches from Hodgkins Seamount; [b] Does not include catches at Bowie Seamount.

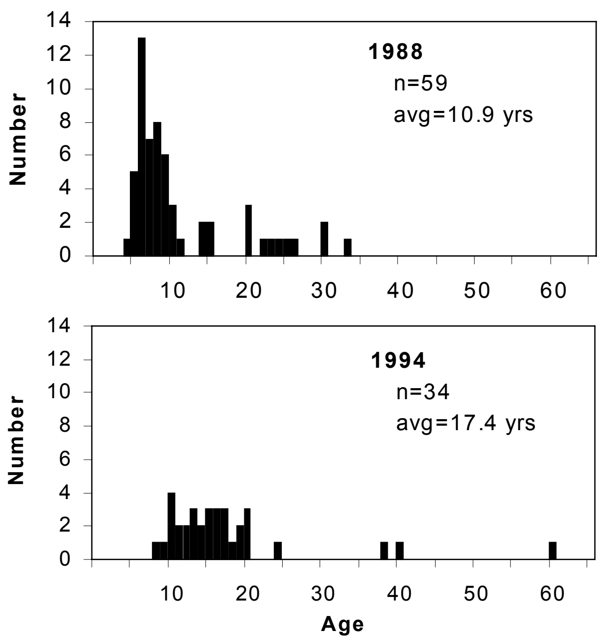

Fig. 3. Age of sablefish sampled at Bowie Seamount in 1988 and 1994. Data from DFO, Pacific Biological Station, groundfish database.

seamount is considered to be both a bonus for fishermen and of little impact on the dynamics of the coastal population. The largest annual catch at Bowie Seamount, of 353.4 t in 1991, was 6.4% of the total sablefish landings in that year. The cumulative catch from 1987 to 2000 was 1451.5 t, and the average annual catch from 1987 to 2000 was 103.7 t or 2.2% of the average annual total commercial landing for the same period.

Sablefish are long-lived and slow growing after maturity. Otoliths were collected for age determination from sablefish at Bowie Seamount in 1988 and 1994 (DFO, Pacific Biological Station, groundfish database). In 1988, 59 of these sablefish were aged; the youngest was 4 years old and oldest was 33 years (Fig. 3), and the average age was 11 years. Thirty-four sablefish were aged from the 1994 sample; the youngest was 8 years and the oldest 60 years (Fig. 3), and the average age was 17 years. Comparison of the age–frequency distribution from the Bowie Seamount with the coastal fishery samples (Saunders *et al.* 1995) indicated that in 1988 and in 1994, the average age of fish on the seamount was older than in coastal areas. Although the sample sizes are small, it appears that the population in 1994 contained many of the same year classes observed in 1988, indicating that there was not substantial recruitment of younger sablefish from 1988 to 1994.

In 1987, 297 sablefish, with an average length of 60 cm, were tagged with Floy Anchor tags at Bowie Seamount (Whitaker and McFarlane 1997). Fifteen of the tagged fish were recovered at Bowie Seamount between 1987 and 1991. Ten of these tagged fish were caught in the coastal fisheries from 1987 to 1996. In addition to the sablefish tagged at Bowie Seamount, 51 sablefish recovered at the seamount from 1985 to 2001 had been tagged in the coastal areas of the continental slope off Canada. The movement of the tagged sablefish into the coastal areas from 1987 to 1996 indicates that some sablefish probably are not permanent residents on the seamount. The recovery of 51 fish on the seamount that were tagged in the coastal areas over a period of 17 years is also evidence that movement on and off the seamount occurs, perhaps on a regular basis.

G. Stauffer and S. McDevitt (unpublished document) experimented with a management approach that assesses stock size and attempts to assess safe catch levels of sablefish as a unit of sablefish habitat. They determined that a catch of 4000 t in the Canadian zone corresponded to a catch rate of 0.13 t/km^2 and was a safe level of removal. It is interesting that the average catch of sablefish in British Columbia in recent years is approximately at this level. The catch of 353.4 t on Bowie Seamount in 1991 corresponds to 3 t/km^2 or 23 times the catch rate of 0.13 t/km^2 that was estimated for sablefish in coastal areas.

Rockfish

The recent commercial catches for rockfish on Bowie Seamount are available from 1990 to 2000 (Table 2). Rockfish fishing was regulated by scientific permit which could be obtained through a co-operative arrangement with a science representative and authorization from the Pacific regions centralized licensing group (Carol Eros, Fisheries and Oceans Canada, Vancouver, *pers. comm.*). The catch of rockfish on Bowie Seamount (Table 2) was additional to the annual quota. No stock assessments were made for the rockfish stocks on the seamount. This catch was assumed to have little impact on the dynamics of the total population, as was assumed with sablefish. The largest catch of rockfish on Bowie Seamount was 440.4 t in 1999. The rougheye rockfish (*Sebastes aleutianus*) portion of this catch was 287.3 t or an astonishing 20.6% of the total Canadian commercial catch of rougheye rockfish in 1999 (DFO, Pacific Biological Station, groundfish database). The accumulative directed catch of rougheye rockfish from Bowie Seamount from 1995 to 1999 was 859.2 t, which is equivalent to 10.8% of the accumulative total catch of rougheye rockfish from all areas from 1995 to 2000. Beginning in 2000, rockfish could not be fished except as bycatch in the sablefish fishery.

Age-determination samples were collected for rougheye rockfish in 1992, 1995, 1996, 1997, 1998 and 2000 (DFO, Pacific Biological Station, groundfish database). Samples indicated that the population is composed of very old fish with mean ages ranging from 42 to 53 years and a maximum age of 105 years (Fig. 4). When compared with ages in the coastal areas (Schnute *et al.* 1999), rougheye rockfish on the seamount are older.

The species composition of the catch reported in the hook-and-line fishery in 1999 (Table 3) identified rougheye rockfish as representing 95.15% of the total catch. However, the hook-and-line fishery is selective for species according to the depth fished and hook size used. Thus, we are using the estimate of 65% rougheye rockfish determined from the 1999 total catch (287.3/440.4) as being representative of the species composition. There are no estimates of the biomass of rockfish on the seamount. The yelloweye rockfish (*Sebastes ruberrimus*) abundance at Bowie Seamount may be up to 6 times greater than in the Strait of Georgia (Lynn Yamanaka, Pacific Biological Station, Nanaimo, *pers.comm.*). Beamish *et al.* (2001) used an estimated 0.5 t/km^2 of yelloweye rockfish in the Strait of Georgia. We used this observation of relative abundance of yelloweye rockfish to estimate the abundance of the other species of rockfish. Carter and Leaman (1982) fished on Bowie Seamount using experimental hook-and-line gear and gill nets. Their catch of 522 kg of yelloweye rockfish and 1815 kg of rougheye rockfish represents a proportion of 22% yelloweye rockfish. If we use an estimate of 3 t/km^2 of yelloweye rockfish on the seamount (0.5 t/km^2 x 6), the estimate for rougheye rockfish would be 13.6 t/km^2. As rougheye rockfish represent 65% of all rockfish, the total rockfish biomass would be 20.9 t/km^2.

Table 2. Total catch of rockfish and rougheye rockfish (*Sebastes aleutianus*) at Bowie Seamount and total commercial catch of rougheye rockfish in British Columbia.

Year	Total rockfish catch (t) at Bowie Seamount	Rougheye rockfish catch (t) at Bowie Seamount[a]	Total Canadian rougheye rockfish catch (t)[a,b]
1990	0.1	0.1	1215.0
1991	17.5	7.4	1006.6
1992	-	-	1671.7
1993	19.2	13.2	1904.2
1994	4.5	4.5	1458.3
1995	134.5	110.2	1908.0
1996	38.9	34.6	1432.4
1997	169.9	133.2	999.8
1998	227.6	182.5	1187.8
1999	*440.4*	*287.3*	1391.9
2000	*270.3*	*111.4*	1070.6

[a] Data from DFO groundfish catch database or from log books. [b] Does not include the catch at Bowie Seamount.

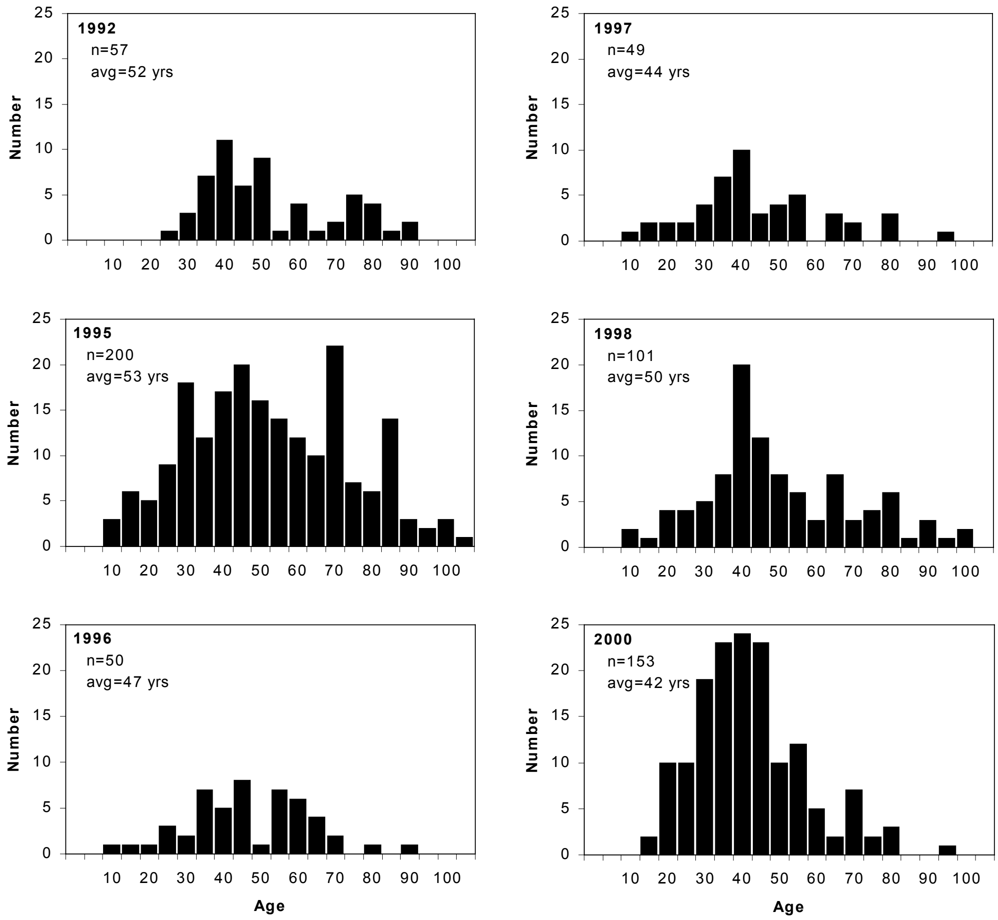

Fig. 4. Age of rougheye rockfish sampled at Bowie Seamount in 1992, 1995–88, and 2000. Data from DFO, Pacific Biological Station, groundfish database.

Table 3. Proportions of rockfish caught by hook and line gear at Bowie Seamount in 1999.

Species	Weight (t)	Percent of catch
Rougheye rockfish	273.34	95.15
Yelloweye rockfish	9.31	3.24
Redbanded rockfish	1.56	0.54
Silvergray rockfish	0.94	0.33
Rosethorn rockfish	0.87	0.30
Widow rockfish	0.70	0.24
Scorpionfish	0.35	0.12
Yellowmouth rockfish	0.13	0.04
Shortspine thornyhead	0.03	0.01
Harlequin rockfish	0.02	0.01
Bocaccio	0.01	0.00
Pacific ocean perch	0.01	0.00
Redstripe rockfish	0.00	0.00
Yellowtail rockfish	0.00	0.00
Quillback rockfish	0.00	0.00
China rockfish	0.00	0.00

Table 4. Functional groups, biomass, production/biomass and consumption/biomass values used in the Bowie Seamount Ecopath model and resulting ecotrophic efficiencies for the balanced model and for the model with 90% reductions in Pacific halibut, sablefish or rougheye rockfish.

Functional group	Biomass	Production/ Biomass	Consumption/ Biomass	Ecotrophic Efficiency			
				Base model	Halibut reduction	Sablefish reduction	Rougheye Reduction
Phytoplankton	75.00	130.00		0.995	0.995	0.995	0.995
Kelp/Sea grass	20.00	34.00		0.488	0.488	0.488	0.488
Herbivorous zooplankton	90.00	20.00	100	0.937	0.937	0.937	0.937
Carnivorous zooplankton	60.00	5.00	25	0.854	0.854	0.854	0.853
Shellfish	35.00	3.00	15	0.983	0.983	0.983	0.983
Crab	28.00	3.50	17.5	0.734	0.727	0.732	0.728
Grazing invertebrates	50.00	3.00	15	0.687	0.687	0.687	0.687
Predatory invertebrates	10.00	5.00	25	0.950	0.949	0.948	0.941
Seabirds	0.10	0.10	5	0	0	0	0
Small pelagics	1.50	2.00	10	0.913	0.909	0.902	0.907
Miscellaneous Demersal fish	10.00	2.10	10.5	0.382	0.372	0.376	0.378
Myctophids	2.50	3.00	15	0.846	0.846	0.839	0.826
Sharks	0.05	0.30	1.5	0	0	0	0
Rougheye rockfish	31.00	0.03	0.15	0.590	0.491	0.530	4.955
Yelloweye rockfish	3.00	0.03	0.15	0.449	0.168	0.359	0.429
Other rockfish	5.50	0.03	0.15	0.580	0.344	0.454	0.437
Sablefish	3.00	0.06	0.3	0.206	0.066	1.613	0.206
Halibut	1.50	0.15	0.75	0.100	0.100	0.100	0.100

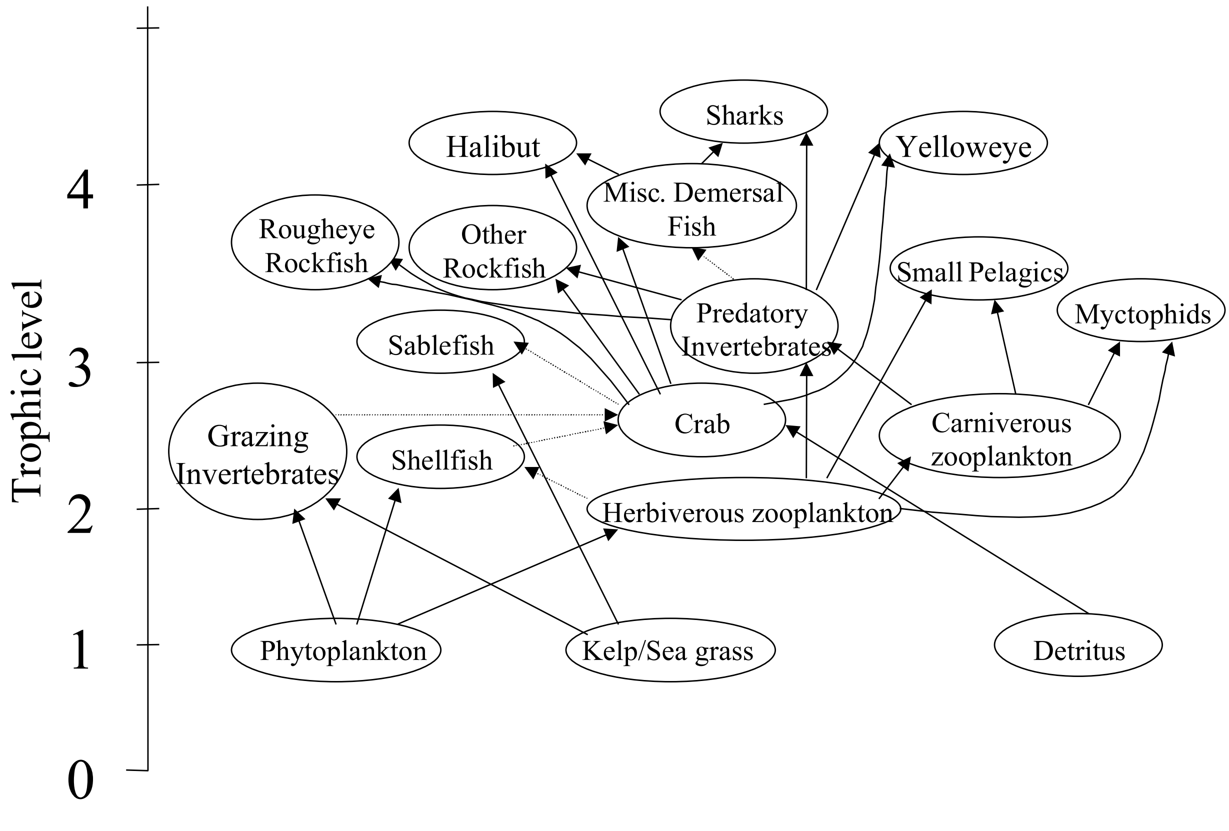

Fig. 5. Ecopath model of major functional groups at Bowie Seamount. The trophic levels represent successive steps in the food chain with groups of animals of common diet, size, and utilization as prey grouped at a particular level. As a general rule, it takes about 10 times the production at one level to support the next highest level.

Table 5. Diet matrix for Bowie Ecopath model.

Prey \ Predator	Herbivorous Zooplankton	Carnivorous Zooplankton	Shellfish	Crab	Grazing invertebrates	Predatory invertebrates	Small pelagics	Seabirds	Misc. demersal fish	Myctophids	Sharks	Rougheye rockfish	Yelloweye rockfish	Other rockfish	Sablefish	Halibut
Phytoplankton	1.000	0.100	0.649	0.002	0.276		0.10		0.005							
Kelp/Sea grass			0.100	0.110	0.300			0.080				0.048			0.300	
Herbivorous zooplankton		0.900	0.200		0.150	0.315	0.300		0.140	0.550		0.120	0.035	0.090		
Carnivorous zooplankton					0.174	0.400	0.310	0.191	0.070	0.350		0.122	0.090	0.125	0.020	
Shellfish				0.148		0.088	0.020		0.080				0.010		0.020	
Crab			0.001	0.060		0.010	0.140		0.339		0.100	0.301	0.341	0.301	0.150	0.600
Grazing invertebrates				0.150		0.100	0.020		0.005	0.100		0.005	0.005	0.005	0.020	
Predatory invertebrates				0.030		0.050	0.100	0.159	0.169		0.260	0.240	0.366	0.250	0.080	0.050
Small pelagics						0.001	0.010	0.320	0.020		0.090	0.010	0.010		0.040	0.010
Seabirds																
Misc. demersal fish									0.072		0.350	0.040	0.005	0.005	0.140	0.200
Myctophids							0.050	0.100	0.049		0.100	0.082	0.130	0.130	0.060	
Sharks																
Rougheye rockfish									0.001		0.050	0.021	0.005	0.023	0.030	0.040
Yelloweye rockfish												0.001		0.002	0.010	0.025
Other rockfish												0.010	0.003	0.002	0.020	0.030
Sablefish															0.010	0.025
Halibut																0.020
Detritus			0.050	0.500	0.100	0.036	0.040	0.150	0.050		0.050			0.067	0.100	

Ecosystem model

We used an Ecopath model (Christensen and Pauly 1992) to represent the trophic relationships at the seamount. The development of an Ecopath model requires estimates of the biomass, production rates, consumption rates and diet of species or groups of species with the ecosystem being studied. The availability of reliable information at Bowie Seamount is very limited. Thus, we based the Bowie Seamount model on production and consumption rates reported in other ecosystems. These assumptions are "best guesses", but it is important to note that the guesses are constrained by a requirement to ensure that food produced by the ecosystem or delivered to the ecosystem must balance the consumption within the system, including production exported out of the ecosystem. Functional groups in this model were determined from the reports of species present. Other information about species composition was compiled from departmental databases (DFO groundfish catch database), published technical and primary reports, communications with scientists and fishermen who have worked at the seamount, and video footage taken at the seamount. We assigned the dominant species from these reports to separate groups and grouped the remaining species into larger functional groups. We excluded highly migratory species such as salmon and tuna because the area of the ecosystem is small. The biomasses of Pacific halibut, sablefish and rockfish in the model were estimated as previously described. Abundances of other species were approximated from relative catch data reported by Herlinveaux (1971), Carter and Leaman (1981), and Carter and Leaman (1982) (Table 4). Production-to-biomass ratios were estimated from natural mortality rates calculated for yelloweye rockfish at Bowie Seamount (Kronlund *et al.* 1999). Rougheye rockfish and other rockfish were assumed to have the same rates. No published diet information for rockfish at the seamounts was available; therefore, diets were estimated from reports of possible prey and from information collected for similar species in other areas (Table 5).

We were unable to find evidence of a substantial small-pelagic community on the seamount. The small-pelagic community is a large and influential group of fishes in many Ecopath simulations. In contrast, the Bowie Seamount ecosystem appears to have a larger proportion of older, slower growing, demersal species.

We used the balanced model (Table 4, Fig. 5), to explore the impact of excessive fishing on key species by reducing the biomass of these species separately and examining the change in the consumption of prey species. More dynamic simulations would better identify the impacts of fishing on the ecosystem, but such simulations would be meaningful only if better diet information existed. We represented overfishing by a reduction of 90% of the current biomass. Although this may seem extreme, target fisheries in such a small area could quickly achieve these levels of reduction. A reduction of halibut increased the production of sablefish, rockfish and crab available to the ecosystem because these were the principal diet items of halibut. The impact of an increasing abundance of these species on the ecosystem was not modelled. As both sablefish and rockfish are cannibalistic, we would expect that these fish would increase in biomass, and would restrict recruitment to the populations. As a consequence, larger, older sablefish and rockfish would dominate the ecosystem. Overfishing of sablefish increased the abundance of crab and rockfish, which could become available to halibut.

The reduction of rougheye rockfish by 90% caused a major imbalance in the model. Rougheye rockfish is both a major predator and a prey species in our model of the ecosystem. In the absence of any substantial small-pelagic fish community, the loss of rougheye rockfish reduced the prey for sablefish and halibut to a level that could not support the existing population. Sablefish and halibut might begin to feed heavily on crab, but may also be stimulated to leave the ecosystem. If the rockfish population is primarily self-sustaining, then overfishing of rockfish could result in a reduced biomass that could persist for decades.

DISCUSSION

Approaches to management

Bowie Seamount is a discrete ecosystem because of its isolation from coastal ecosystems. However, the known species composition is similar to the composition found in the coastal areas except that the seamount fauna may be less diverse. The small-pelagic community appears to be sparse when compared with the trophic structure observed in coastal waters, although the studies of species composition are minimal. The top predators at the seamount all tend to be long lived, perhaps suggesting that the habitat is suitable for the survival of these species but less suitable for reproduction or that recruitment may come from coastal areas. The apparent high abundance of sablefish and rockfish would support this possibility, because these species grow very slowly and thus their production relative to their biomass is low. Halibut, however, are large, fast growing predators, which would suggest that they prey heavily on the other species in the Bowie Seamount ecosystem. The large size of the halibut fished in 1990 might indicate that they remain on the seamount for many years because of the abundance of prey such as crab, sablefish, rockfish, and perhaps squid. If this interpretation is approximately correct, there must be an abundant food source available to these halibut. As no stomach-content data were available for halibut, we can only speculate that crab are a major component of their diet, because crab are reported to be abundant on Bowie Seamount. The video footage and the reports from the fishermen indicated that there were large incidental catches of rockfish, especially yelloweye rockfish. Thus, it is possible that rockfish are also a prey of halibut although rockfish are not reported as being a major prey of halibut in the coastal areas (Best and St-Pierre 1986). Halibut have been reported to live up to 55 years (Forsberg 2001); hence, halibut might have remained on the seamount for long periods in the past.

The youngest sablefish aged in 1998 was 4 years compared with 8 years in 1994. This suggests that recruitment at the seamount may occur intermittently. The impact of the fishery on the sablefish population on the seamount and the impact of the sablefish fishery on associated species remain to be assessed. An immediate requirement is to assess the age composition of the present population. The tagging data for sablefish indicate that there is movement onto and off the seamount. There is no evidence that immature fish occur on the seamount, but it is known that immature sablefish rear in areas that are not common habitat for mature sablefish. Thus, it is expected that immature sablefish would not be common on the seamount. One explanation of the movement onto and off the seamount is that there may be a tendency for some sablefish to migrate more than other types. If there are resident and migratory types, the population of sablefish on the seamount may consist of a higher percentage of the "transient" type than found in the coastal areas.

There is evidence from parasite studies that the sablefish on Bowie Seamount are discrete from sablefish in coastal areas (Kabata *et al.* 1988). In addition, the parasite composition found in sablefish at Bowie Seamount differs from the parasite composition found at other seamounts in the Northeast Pacific (Whitaker and McFarlane 1997). One explanation is that the parasites are common to Bowie Seamount and would occur in sablefish in coastal areas only if the fish had lived previously on the seamount. As such fish would be rare in the coastal population, the probability of sampling them would be low and it would appear that the parasite is not found in the coastal population. It is apparent that there is much to learn about the dynamics of sablefish on Bowie Seamount and it is even possible that the research on this population may provide new and fundamental information about the biology and behaviour of sablefish.

Rockfish may need to be self-sustaining at the seamount because they have internal fertilization and give birth to larval rockfish. Localized distributions of rockfish larvae have been observed around the seamount (Carter and Leaman 1981). Recent DNA evidence for yelloweye rockfish, however, identified that the Bowie Seamount fish are not genetically distinct from coastal stocks (Yamanaka and Lacko 2001). This indicates that there is a linkage with coastal stocks, but does not provide information on how the linkage occurs and over what time frame. In addition to not understanding how the seamount stocks are linked, there is the problem of how to manage any species of fish that is long lived. Currently, the approach is to use a lower fishing mortality compared to younger, faster growing species such as Pacific salmon. However, this approach causes a change in the age structure of the population that results in the loss of most of the older fish and an abundance of younger fish sometimes aggregated around the age of maturity. Presumably, natural ages (Munk 2001) that range up to 94 years for sablefish, 205 years for rougheye rockfish, and 118 years for yelloweye rockfish are adaptations to natural processes that affect recruitment. The time frame of the influences of these natural impacts is long relative to our own lifespans as individuals and as managers. Thus, the importance of longevity has virtually been ignored in our management strategy. We suggest it is time to begin to understand how to manage the long-lived fishes that are a common feature of our Pacific groundfish fisheries and we suggest that these studies could be undertaken at Bowie Seamount.

A preliminary ecosystem based estimate of fishing on Bowie Seamount

Our application of Ecopath to model the Bowie Seamount ecosystem necessitated the use of information from other ecosystems. Our model identifies reduced consumption and increased survival of rockfish and sablefish when Pacific halibut are overfished (90% reduction). The impact of an increased abundance of these species could be assessed, and a more dynamic simulation made, if accurate diet information were available. The most significant immediate impact of fishing on the ecosystem would result from overfishing rockfish. According to our model, rockfish are an important prey for halibut and sablefish. Reduced rockfish abundance would require that halibut and sablefish either switch to eating other species or leave the seamount. These impact scenarios are intended only to show the interdependency of species. The ultimate requirement is to be able to schedule fishing mortality such that the impact of the removal of target species is managed with respect to the interspecific relationships. If we are correct in our interpretation that the diversity of species in the Bowie Seamount ecosystem is reduced by a virtual absence of a small pelagic community, then excessive removals of some of the key predators may change the species composition in a manner that could persist for decades.

In a sense, our approach examines the bigger picture before the detail is available. Our model is a framework that can be used to identify information that needs to be collected. Basic studies of diet are essential. Age compositions of catch are needed to study the productivity of resident species. A better understanding of the role of small pelagics is an essential part of forecasting the impacts of fishing on the ecosystem. The ecosystem model highlights the need to acquire non-traditional data from a fishery. We suggest that the importance of establishing ecosystem-based fishing policies becomes clearer when models are available to managers. In another report we propose that policy should begin with an ecosystem bill of rights that is a statement of principals recognizing our shared use of habitat (Beamish and Neville 2003).

Future management of Bowie Seamount

We propose that Bowie Seamount will better serve as an experimental ecosystem than as an area protected from all fishing, because Bowie Seamount has already been fished extensively. It is important that this site be thoroughly monitored in the future and that the data be available to experimenters and interested clients. It should not only be the scientific community that follows the developing appreciation of the linkages among fishing, ocean dynamics, and climate change in this experimental ecosystem. Public education would be an important part of the program. Students at the elementary and high school level can be connected to the project and over their lifetime they will be able to check on progress and develop an appreciation of the processes that affect ecosystems. An experimental approach will teach marine ecosystem science, not from theory, but from the ecosystem itself. All clients of the Department of Fisheries and Oceans can develop their own understanding of the processes and patience that are required to learn about ecosystems.

Science is the testing of ideas. Future studies at Bowie Seamount including fishing would have clear objectives that would be presented as ideas that are being tested. Some ideas will turn out to be right and some will be wrong. Canadians monitoring this project will see that good science can occur by rejecting ideas. Canadians will understand that being precautionary in management is logically related to our level of understanding.

In the future, establishment of additional experimental areas for ecosystem research in coastal areas would facilitate comparisons. The USA could be encouraged to create similar experimental ecosystem-management areas for seamounts in the Gulf of Alaska. Canada could promote the establishment of an international association of marine experimental ecosystem-research areas. An association of such areas would provide a way of detecting and studying large-scale climate impacts or common management issues such as the impact of exotic species and containment. Bowie Seamount is one of a few ecosystems where there is very little contamination. Thus, maintaining this "contaminant-free" area will ensure that background or control areas are available for contaminant research.

One of the important contributions of the Bowie Seamount experimental research area could be the development of a system that improves our ability to manage unexpected events. We know as biologists that we should expect the unexpected. Unexpected events occur because of our limited understanding of how communities function and because of our requirement to study species and processes of immediate importance. Imagine what we would have done with government resources in the 1970s if we had known that abundance of Canadian Pacific salmon was low because the capacity of the ocean to produce salmon was low relative to the long-term average, and that this condition would change naturally to a productive state. This concept was unknown in the 1970s, just as some "unknowns" important to future management exist today. A network of experimental ecosystem areas, for example, can provide the study sites needed to detect impacts of climate change. The experimental-ecosystem-areas approach can be used to detect synchrony in change which would normally be indicative of large-scale change caused by common factors such as climate. Species of interest can differ among areas, but the synchrony in change turns all species into large-scale indicators of ecosystem change. Migratory species including birds and marine mammals may also be of immediate interest among seamounts, because these species move among the study sites. There are species such as midwater fishes (myctophids) that may be the most common of open-ocean fishes, yet they are poorly studied, particularly at Bowie Seamount. A focus for ocean ecosystem studies would encourage research on these poorly known species.

Experimental ecosystem-research areas would provide science in support of marine protected areas. The study of whole ecosystems would help establish priorities in science and move management into a new era of ecological forecasting. Experimental ecosystems provide advocates of marine protected areas with an opportunity to integrate their objectives with fisheries managers. We recognize the value of fish habitat in fresh water, but we are only beginning to understand the importance of fish habitat in the three-dimensional world of the ocean. We are also only beginning to recognize that essential habitat extends to all life-history stages.

It is probably correct that at this time science cannot tell us how to carry out an ecosystem-based management approach. However, the job will get tougher if we wait, because the impacts of global warming will further complicate ecosystem-based management. The experimental-ecosystem approach establishes a learning system for the community through partnerships and cooperation. Communication of the purpose and the progress of the study of the Bowie Seamount will allow all Canadians to share in the excitement of discovery.

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THE NEW ZEALAND SEAMOUNT MANAGEMENT STRATEGY – STEPS TOWARDS CONSERVING OFFSHORE MARINE HABITAT

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Abstract

Information suggests that seamounts are areas of high biological diversity. The fishing industry in New Zealand has actively sought out seamounts as a means of finding new fishing deepwater grounds. Bottom-trawl fisheries may have significant and long-lasting impacts on the benthic habitats and faunas. The Ministry of Fisheries in New Zealand has developed a draft strategy to address these adverse effects on a representative sample of seamounts in New Zealand waters; this has entailed the closure of 19 seamounts to trawling, a strategy accompanied by a programme of research. The measures have not met with universal approval and a number of key policy issues still need to be resolved. In the course of addressing those issues, the management of seamounts is acting as a test case in New Zealand of how the environmental impacts of fishing can be addressed in a way that satisfies different and sometimes competing objectives.

Keywords: Seamounts, New Zealand management measures, Representative sample, New Zealand research, New Zealand seamount strategy

INTRODUCTION

This paper outlines the main components of management of seamounts in New Zealand. New Zealand has 19 seamounts closed to trawling. They are closed by statutory regulations in accordance with a draft strategy developed by the Ministry of Fisheries to address the adverse effects of fishing on seamounts. This paper outlines the key issues that arose in the development of the strategy and the steps taken to close the 19 seamounts. A brief description is also given of some of the research undertaken in support of the information needs of the strategy.

The paper concludes by looking at some of the challenges ahead and the potential role that research could play in providing information for decision makers in the future.

THE NEW ZEALAND SEAMOUNT STRATEGY

New Zealand has closed 19 seamounts to all forms of trawling. A common question is why were seamounts chosen for special treatment amongst the range of environmental issues affecting fisheries management.

Part of the rationale for identifying seamounts as requiring specific management is the number of seamounts found in the New Zealand region, the targeting of seamounts by deepwater fisheries and the potential vulnerability of seamount fauna to the effects of fishing. A second key reason is the nature of the domestic legislative provisions. Legislation governing fisheries in New Zealand contains principles relating to the need to address the adverse effects of fishing on the aquatic environment.

Seamounts within the New Zealand Region

Seamounts are a prominent feature of the New Zealand bathymetry. The country straddles Indo-Australian and Pacific tectonic plates. Active volcanic ridges run down the length of the New Zealand's Exclusive Economic Zone (EEZ), and New Zealand's geological history has involved much temporary hotspot volcanism as well.

Some 800 seamounts (with a virtual elevation of >100 m) are known within the New Zealand region. They are distributed throughout the EEZ and beyond, with the greatest concentration being in northern waters and across the Chatham Rise (Fig. 1).

Most of the seamounts are relatively small, less than 100 sq km; many are less than 20 sq km in overall size. The depth at the peak ranges from 20 to 6500 m, with most within 500 to 1250 m depth range. Of the known seamounts, 70% have less than 1000 m elevation. The seamounts have differing geological origin, the majority being mid-plate volcanoes.

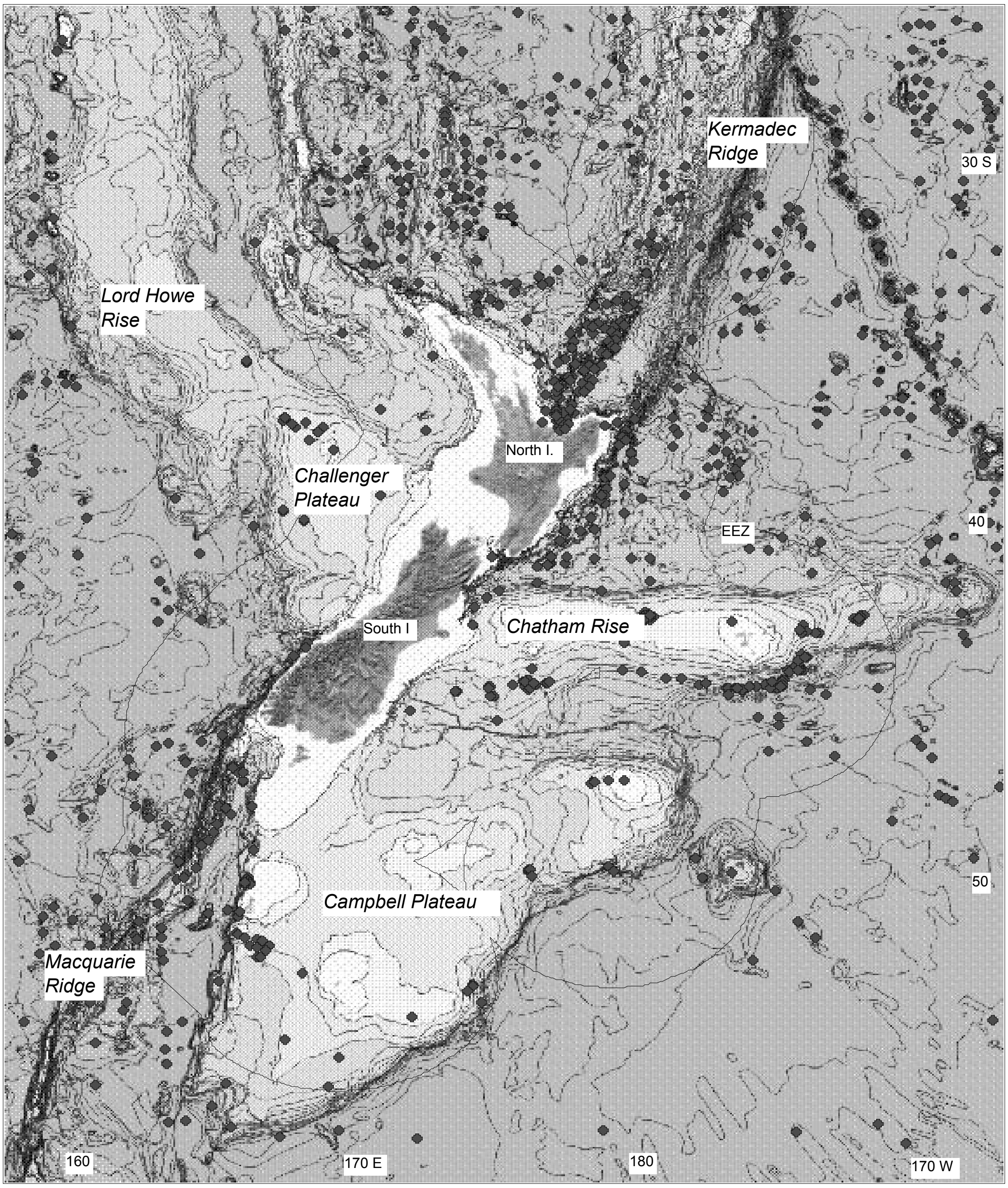

Fig. 1. Distribution of seamounts in the New Zealand region with vertical relief greater than 100 m.

Commercial fish species that are targeted on or around seamounts in New Zealand fisheries waters include rubyfish, alfonsino, bluenose, black cardinalfish, orange roughy, black oreo, and smooth oreo (Clark 1999; Clark and O'Driscoll in press). The total catch of these species amounts to around 40,000–45,000 tonnes per annum (Annala *et al.* 2001) which makes them valuable New Zealand fisheries. Although several of these fisheries began on the general continental slope, over time many have become increasingly focussed on seamount features (Clark and O'Driscoll in press), and such habitat is actively targeted in the search for new deepwater fishing grounds. The fishing industry has actively sought out seamounts as a means of finding new orange roughy grounds, and about 80% of those known seamounts at orange roughy depths have now been trawled.

The commercial species associated with seamounts are targeted primarily with mid-water and bottom trawl gear. A mid-water trawl net is generally of lighter construction and a higher headline height (i.e. size of net opening). Bottom trawl nets are heavier than mid-water nets, with heavier ground chains, bobbins, and trawl doors, and with a lower headline height. However, although fishers seek to minimise damage or loss of gear, in practice there may be little difference between the two types of gear in terms of potential impacts on the seabed. The use of trawl nets, both mid-water and bottom, is not restricted to their respective levels in the water column. Mid-water nets can be placed on the seabed and used in bottom trawling, and bottom trawl nets can be used to target fish slightly off the seabed. Hence, it is difficult from a management perspective to make any effective distinction between mid-water and bottom trawl nets.

There is much published literature (see review by Rogers 1994) on seamounts, which identifies them as being important habitat because of the presence of unique and vulnerable benthic fauna. Information from the Northern Hemisphere suggests that seamounts are areas of high biological diversity and potential endemism and, being often in deep water, potentially have low productivity rates and slow recovery from human impact. They are also often high productivity areas, and are significant for spawning aggregations for some commercial species.

The use of bottom (and to a lesser extent mid-water) trawl gear that comes into contact with the seabed has a significant impact on the areas fished. Effort is highly concentrated on seamounts, and trawling can be very localised. Such features are often small, only a few sq km in area, yet can have several hundred trawls running over them each year. This can put significant pressure on the ability of sessile benthic invertebrates, in particular, to survive.

The composition of benthic fauna associated with seamounts in New Zealand, and the damage caused to seamount ecosystems by fishing methods, has yet to be comprehensively assessed. The degree of endemism of benthic flora and fauna on individual seamounts in New Zealand's region is unknown. However, the literature indicates that the habitats present on seamounts, and the associated fauna, are fragile and vulnerable, and bottom-trawl fisheries may have significant and long-lasting impacts on the benthic habitats and faunas (Clark *et al.* 1999).

Domestic legislative obligations

The *Fisheries Act 1996* (the Act) is the principal legislative mechanism by which the adverse impacts of fishing on the aquatic environment, including seamounts, should be addressed. The only tool for managing those effects is under fisheries legislation. In New Zealand, legislation does provide for the use of marine reserves beyond the territorial sea.

The Act provides for dual objectives of "ensuring sustainability" and "to provide for … utilisation of fisheries resources". The extent of management measures required to ensure sustainability will produce a continuum of possible outcomes that may allow for different levels or forms of utilisation.

The provisions of the Act also contain specific obligations relating to the aquatic environment and the effects of fishing. The statutory obligations are in the form of generic principles that need to be taken into account, namely:

- adverse effects of fishing on the aquatic environment are to be avoided, remedied, or mitigated,
- biological diversity of the aquatic environment should be maintained,
- habitats of particular significance for fisheries management should be protected, and
- associated or dependent species should be maintained above a level that ensures their long-term viability.

The definition of the term "effect" is broad and includes the following: any temporary or permanent effect; past, present, or future effect; cumulative effect; potential effect of high probability; or potential effect of low probability which has a high potential impact.

The use of the word "potential" in the definition suggests that fisheries managers should consider a range of possible future effects, rather than only focus on the known effects that science has been able to prove. The knowledge regarding seamount ecosystems in New Zealand waters is limited. The potential for species endemic to New Zealand to occur only in a relatively discrete area poses a risk that these species could become severely depleted and ultimately extinct as a result of the adverse effects of bottom fishing methods.

Content of the Seamount Strategy

The absence of complete information on the importance of seamounts, the role seamounts play in the aquatic environment, and the biology, abundance, and distribution of species associated with seamounts is acknowledged. However, the available information indicates the need to implement a prudent management strategy.

The Ministry considers that the implementation of a strategy to manage the impacts of fishing on seamounts is a prudent management response that recognises the available information and is consistent with the obligations found in domestic legislation and international law.

The key objective of the strategy is the implementation of measures to manage the impacts of fishing on a representative sample of seamounts in New Zealand waters. The strategy establishes a two-step process of first identifying potentially representative seamounts (based on scientific criteria) and then selecting those seamounts that will form part of the representative sample (taking into account social, economic and cultural factors). The strategy also identifies potential management measures and implementation options. The range of potential management measures includes closure to all forms of fishing, water-column restrictions, and fishing-method restrictions (prohibiting the use of those methods that affect or have the potential to affect seamounts), and area restrictions on individual seamounts or a chain of seamounts or hill structures. The management measures can be implemented by statutory regulation or industry measures, such as codes of practice. An incremental approach to the development of the strategy is envisaged – the strategy will evolve over time as the state of knowledge improves, thereby enabling the adequacy of existing measures to be reviewed.

Definition of a seamount

The aquatic environment contains a range of geological structures. Many fishing operations are based, in part, on features that for convenience are collectively labeled "seamounts", but in reality consist of features of various forms, including knolls, pinnacles, and common "hills". The meaning of the term "seamount" for the purposes of this strategy is of importance to ensure that parties are fully aware of the scope of the seamount strategy.

A seamount can be defined by the height of the structure from the sea floor. In geological terms a "seamount" is a structure that rises 1000 m or more from the seafloor. In the development of the seamount strategy the Ministry of Fisheries considers that this definition is overly restrictive and fails to encompass the general intent of the seamount strategy, namely to address the adverse impacts of fishing on bottom features. The strategy, therefore, defines a seamount for the purpose of the seamount strategy as protruding irregularities, or bottom features, that rise greater than 100 m above the sea floor in any depth of water. Seamounts can either be 'stand-alone' features, or form part of a chain or hill range. This definition provides sufficient flexibility to enable measures to be implemented where specific features are subsequently identified through research as being of significance.

The definition adopted in the seamount strategy has been a source of contention. A view held within the fishing industry is that use of the term "seamount" misrepresents the scope of the strategy and plays upon that popular perception that seamounts are "jewels of the ocean" with high levels of biodiversity.

The Rationale behind the representative sample

The sample group would be spread over the potential representative range of biodiversity and habitats represented on the seamounts. The aim of the management measures undertaken in respect of the representative sample is to ensure sustainability of seamount ecosystems while providing for use, maintaining biodiversity, and meeting the foreseeable needs of future generations.

The closure of a representative sample of seamounts is also consistent with the information principles contained in the Act. Section 10 requires that a cautious approach should be adopted for fisheries management where information is uncertain, unreliable, or inadequate. Decisions should be based on the best information that, in the particular circumstances, is available without unreasonable cost, effort, or time. Decision makers should consider any uncertainty in the information available in any case and be cautious when information is uncertain, unreliable, or inadequate. The absence of, or any uncertainty in, any information should not be used as a reason for postponing or failing to take any measure to achieve the purpose of the Act.

By specifically managing a representative sample of bottom features the Ministry considers that a significant step would be taken to address the obligation to avoid, remedy, or mitigate any adverse effects of fishing on the aquatic environment. The Ministry considers it is reasonable to take these steps, while providing for utilisation through the fishing of the majority of bottom features.

What constitutes a representative sample?

To determine a representative sample requires the stratification of seamounts found in New Zealand waters. The Ministry notes that one means of identifying the potential range of seamounts likely to be found is by geographic location. There are also other criteria to take into account, for example water mass, depth in water column, and sediment types. Within a particular area there may also be a range of types of seamounts that would be included in a comprehensive sample.

Criteria for Identifying and Selecting Suitable Seamounts

The identification of criteria for identifying and selecting seamounts for specific management is an important aspect of the seamount strategy. The adoption of these criteria enhances the transparency of the decision-making process and ensures that seamounts are not chosen on a purely arbitrary basis. The criteria for identification of candidate seamounts are based primarily on biodiversity and environmental factors (i.e. premised upon sustainability). Social, cultural, and economic criteria (i.e. premised upon use) are applied in the selection of seamounts from the candidates originally identified. The purpose of a two-step process is to allow the assessment of scientific information to be considered separately from the different interests in the particular seamount.

The criteria for the identification and selection of seamounts have been developed from the "Guidelines for Establishing the National Representative System of Marine Protected Areas" developed by the Australia and New Zealand Environment and Conservation Council (ANZECC) Task Force on Marine Protected Areas (ANZECC 1998).

Process for identification and selection of seamounts

To implement a strategy to manage a representative sample of seamounts, some process for identifying and then selecting seamounts needs to be adopted. The Ministry of Fisheries used the criteria developed by the ANZECC Task Force on Marine Protected Areas in its Guidelines for Establishing the National Representative System of Marine Protected Areas.

The criteria for identification of a suitable sample of seamounts are:

- **Representativeness -** the degree to which the seamount is representative of other seamounts in the area.
- **Comprehensiveness –** the extent to which the seamount adds to the range of different seamount included in the sample.
- **Ecological importance and uniqueness** – the extent to which the seamount supports species that are either endemic to the seamount or to New Zealand, and the importance of the habitat for spawning or juvenile nursery grounds, etc.
- **Productivity -** the high natural biological productivity of the species, populations, or communities on the seamount may be due to some unique aspect of the area or seamount and may warrant specific management action.
- **Vulnerability assessment** – an assessment, based on best available information, of the susceptibility to human-induced or natural change.
- **Naturalness** – the extent to which the seamount has been subject to human-induced changes. Selection of a range of seamounts, such as unfished, lightly fished, moderately fished, or heavily fished seamounts, may enable growth and regeneration of flora and fauna on the seamounts to be monitored.

The criteria for final selection of suitable seamounts are:

- **Social interest –** the existing or potential value to the local, national, or international community in respect of economic, educational, recreational, cultural, inter-generational or traditional values
- **Scientific interests** – accessibility for scientific research and monitoring.
- **Economic interests** – the existing or potential economic interest or activities in an identified seamount.
- **Practicality/feasibility of management –** isolation from other external destructive influences, e.g. mining or exploratory drilling for petroleum; degree of acceptability from various sectors; and likely compliance with the management measures in order for management to be effective.
- **Customary Maori interests –** any present or future customary Maori use will need to be taken into account when selecting seamounts for management. (At present there are no records of traditional fishing practices on deep-sea seamounts; however, a number of 'seamount' features are within 'coastal' inshore waters.)

THE CLOSED SEAMOUNTS

The second major step as part of the management of seamounts in New Zealand has been the closure of 19 seamounts.

The National Institute of Water and Atmospheric Research (NIWA) was commissioned by the Ministry of Fisheries to identify suitable seamounts in terms of the criteria set out in the seamount strategy. The Ministry recognised that in the short term there was likely to be little information that could be used to assist with any comparison among suitable sites. As a means of determining what may constitute a potential representative sample of seamounts, four basic bio-geographic regions within New Zealand waters were identified:

- Northern North Island: Bay of Plenty/Kermadec, subtropical influence, numerous peaks along the Colville and Kermadec Ridges,
- Western New Zealand: Mainly subtropical surface waters, single isolated features in the northern region,
- Eastern central New Zealand: Subtropical convergence zone, numerous small seamounts along the flanks of the Chatham Rise, and
- Southern area: Sub-Antarctic, a mixture of small peaks along the plate boundary and margins of the southern plateau, as well as large features further offshore (e.g. Bollons seamount).

Within each of those broad areas a number of other factors were identified as being likely to influence the species distribution found on and around the seamounts:

- Depth in water column (because fauna changes with depth, e.g. photic zone <200 m, then another change at ~1200 m);
- Elevation (seamounts in New Zealand range from 100 m height to several thousand metres);
- Area (ranging from <1 km^2 to >10,000 km^2);
- Gradient (ranges from 5º to >60º);
- Water mass at depth (different from surface, affects temperature);
- Sediment types (e.g. ooze, coral, rocky, often heterogeneous on any single seamount);
- Geological origin (volcanic, on tectonic boundary, or mid-plate, continental block); and
- Geological association (oceanic, well away from shelf/slope, or continental).

On the basis of the factors identified above, NIWA identified 19 seamounts. Fisheries stakeholders were provided with the opportunity to identify alternative seamounts if they had a particular interest in one of the seamounts identified. No alternatives were identified by fisheries stakeholders. The Government elected to implement measures in respect of all 19 seamounts.

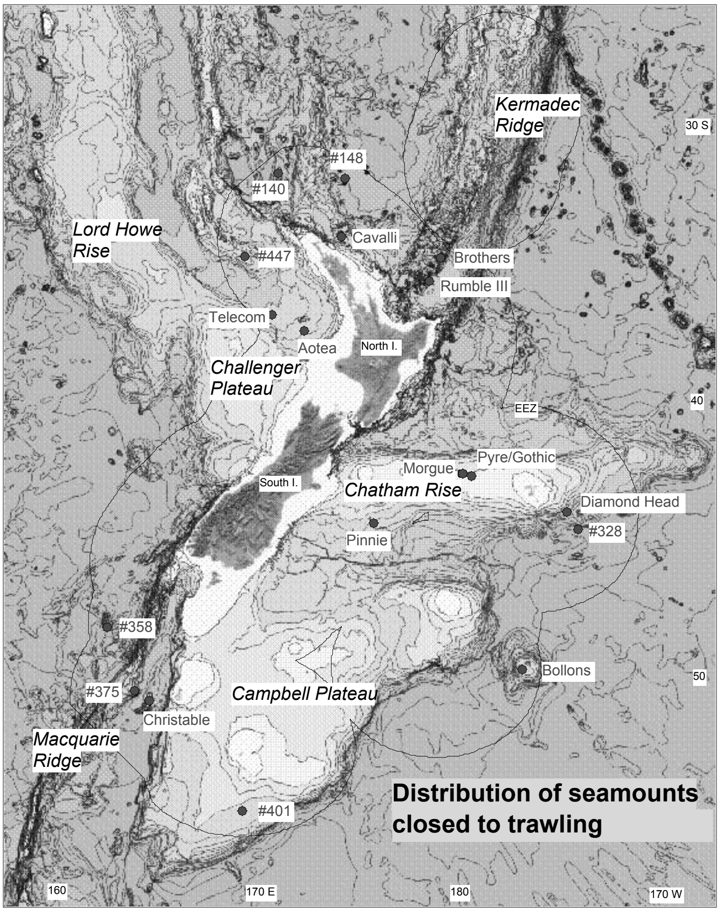

Fig. 2. Location of closed seamounts in the New Zealand EEZ.

Table 1. Characteristics of closed seamounts

Name	Depth	Elevation	Area (km^2)	Origin	Region
Aotea	900	1200	500	Unknown	Western
Telecom	1500	250	20	Unknown	Western
#447	615	650	120	Unknown	Western
Pinnie	600	200	5	Intraplate volcano	Eastern
Morgue	890	310	3	Intraplate volcano	Eastern
Pyre	1004	200	1	Intraplate volcano	Eastern
Gothic	987	170	2	Intraplate volcano	Eastern
Diamond Head	603	500	3	Intraplate volcano	Eastern
#328	1750	1200	600	Rifted margin volcano	Eastern
#148	677	2600	190	Arc volcano	Northern
Cavalli	538	1050	125	Unknown	Northern
#140	1750	2900	590	Arc volcano	Northern
Brothers	1197	1300	35	Arc volcano (active)	Northern
Rumble III	200	3200	300	Arc volcano (active)	Northern
#358	1652	2400	2000	Intraplate volcano	Southern
Bollons	800	3600	35000	Rifted continental block	Southern
#375	684	570	460	Tectonic ridge	Southern
Christable	910	2400	2170	Unknown	Southern
#401	1159	340	200	Continental Rise	Southern

Information on the 19 closed seamounts

The 19 seamounts cover a broad geographical range in the New Zealand Exclusive Economic Zone (Fig. 2). All but one of the seamounts had been fished. Two seamounts on the Chatham Rise are close to each other – one is fished, one unfished.

The seamounts vary across a range of characteristics – depth at peak, elevation (height of peak above the surrounding seafloor), size, geological nature and biogeographic regions (see Table 1). At least three seamounts are within each of the four broad biogeographic regions identified in the strategy.

Management measures adopted

The Government considered potential implementation of a range of management options. As a preference, the 19 seamounts were to be closed only to those methods that had the potential to adversely affect the seamount benthos. However, the effectiveness of the existing compliance regime was a key factor in determining the measure chosen.

A range of species is caught, using different fishing methods, throughout the water column above seamounts. By use of the vessel monitoring system, it is possible to distinguish between trawlers and long liners. Therefore there was no need to implement a total closure of the seamounts. Mid-water trawl gear may never come into contact with the bottom. Yet mid-water trawling occurs in close proximity to the bottom and may still on occasion, inadvertently, result in damage to the seamount. The ability to distinguish between mid-water and bottom trawl gear or to provide a clear definition of the respective methods is problematic. There is the potential that fishers would modify gear to suit whatever definition was applied.

The placement of observers on every boat was considered. However, there were major reservations about the ability of observers to interpret net-monitoring devices, GPS information, and position of the trawl gear (bobbins, etc.) on a real-time basis. There is no guarantee that even with mandatory observer coverage and net-monitoring devices there is an ability to determine conclusively whether a net contacted with the bottom. Observers will be able to detect obvious signs of contact such as coral or rocks in the catch or damage to gear. No system was identified that could be used to retrospectively determine whether the trawl gear avoided physical contact with the seamount.

The strategy does not discount the possibility of managing part of a hill structure or limiting fishing activity to only parts of a seamount or along certain trawl lines. However, the ability to effectively monitor fishing and to provide certainty as to the actual boundaries of the closed areas is a significant limitation. Further, it is not known what are the potential flow-on effects (such as increased sedimentation) when fishing is allowed relatively close to a protected area.

The outcome was a decision to close the 19 seamounts to all forms of trawling. The seamounts were enclosed within a box structure that created a buffer area of sufficient size to preclude the manoeuvring of trawl gear over the seamount. The area was defined by determining the point at which the seamount met the general contour of the surrounding seabed. The coordinates of the boxes were defined so as to provide certainty to fishers as to the precise location of the closed areas. The areas are large in size because of the accuracy of reporting requirements (1 minute of latitude/longitude), and at times they overlap open seamounts. The total area closed to trawling amounts to about 100,000 sq km. The actual area of the seamount features within the closed boxes totals about 40,000 sq km, just >1% of the area of the New Zealand EEZ.

Consideration was given to two possible means of implementing the seamount closures – regulatory and voluntary measures (i.e. by industry code of practice). Statutory regulations should not be put in place without the means to ensure enforcement. As a general principle, the Ministry of Fisheries has preference for measures being effected on a voluntary basis – a high degree of voluntary compliance is advantageous even in the case of regulations. Use of voluntary measures tends to place incentives on industry to provide for effective management of the fishery. However, voluntary measures need to have unanimous support. Adequate measures would need to be put in place by industry internally to ensure compliance. The lack of sanctions for any breach of voluntary measures is a significant limitation, whereas the potential cost to the environment of non-compliance may be potentially high.

The Government considered the use of an industry code of practice. The inability of industry at the time to develop a viable code of practice that incorporated a means of auditing and monitoring the performance of industry became a major limitation. The Government elected to implement the closures by way of regulation. However, it signalled a willingness to remove the regulations if a comprehensive code of practice could be developed by industry.

PRESENT RESEARCH

Research has been an important element in the formulation and future planning of the strategy. Two research institutes within New Zealand are carrying out science programmes on seamounts: The National Institute of Water and Atmospheric Research (NIWA) which has a biological focus on biodiversity and impacts of fishing, and The Institute of Geological and Nuclear Sciences with an emphasis on geological processes. The NIWA programme on "Seamounts: their importance to fisheries and the marine ecosystem" is funded largely by the Foundation for Research, Science and Technology, with support from the Ministry of Fisheries and Department of Conservation. The NIWA research programme is designed to investigate the ecology and functioning of seamount ecosystems, as well as to determine the impacts of human disturbance.

The objectives of the research undertaken by NIWA are to an extent designed to support the information needs of the Seamount Strategy. The research to date has provided information on:

- Location of seamounts
- Physical characteristics
- Biodiversity
- Variability between seamounts
- Seamount processes and dynamics
- Impacts of fishing

An important element in the past year has involved surveys of closed seamounts to identify their biodiversity, and to feed this information into the design of a network of representative seamounts to be considered for protection. It is early days yet, and researchers face a large task in describing the diversity of seamount types and providing comprehensive information on biodiversity within and between a large number of features, but results to date more than justify the selection of the 19 seamounts closed to trawling.

Surveys using small epibenthic sleds and still- and video-photographic equipment have been carried out on 4 of the closed seamounts or groups. These surveys have revealed marked differences in the faunal composition among the relevant seamounts:

- Cavalli seamount: dominant fauna found to be gorgonian and scleractinian corals, and sponges;

- Rumble III and Brothers seamounts: particular significance was the discovery of hydrothermal vent fauna, largely unknown in New Zealand waters until these surveys, together with brachyuran and anomuran (especially galatheid and pagurid) crustaceans;
- Northwest Chatham Rise seamounts (including Morgue, Pyre, Gothic): scleractinian corals were common, with crabs also;
- Aotea: little coral was found, but pagurid crabs, gastropds, and brittle stars were prominent.

In addition to the diversity between these seamounts, the research is also uncovering a large number of new species, or new records for the New Zealand region. For example, on the Northwest Chatham Rise seamounts, more than 50 of the approximately 400 invertebrate species recorded were new or previously unrecorded (Rowden *et al*. 2002). The extent of endemism is uncertain without more sampling, but the research suggests that there is a strong element of seamount fauna having a very localised distribution.

The research programme is still relatively new, and scientists are only just beginning to understand the variety of fauna on seamounts. However, the Seamount Management Strategy is providing a solid platform to protect the benthic habitat and biodiversity, yet still enable fishing to continue.

KEY ISSUES TO DATE AND THE WAY FORWARD

Key issues

Two of the key issues confronted in the development of the seamount have already been outlined – namely definition of a seamount and options for management of the water column. Other key issues have been the necessity for management action to be taken and the nature of the action required.

Sector-group opinion on this issue is polarised between the absence of any need to act and the need to close all unfished seamounts. Industry contends that there are a vast number of seamounts of which only some are fished, and of those fished some seamounts can be fished only on certain parts. Industry also is reluctant to accept that the Fisheries Act can be used for purposes of environmental protection. Conversely, the environmental NGOs advocate closure of all unfished seamounts, given the potential for loss of species. The Government's approach is that management measures should not wait for the availability of information that can answer such issues but that prudent measures should seek to address the degree of risk posed by the impacts of fishing to seamounts. However, there remains the potential for industry to challenge the measures implemented to date by filing legal proceedings against the Government.

The closure of the seamounts has been undertaken under fisheries legislation; there are a number of potential human impacts on the seamounts not covered by those measures – most notably mining activity. The Ministry of Fisheries has undertaken initiatives to ensure that compatible measures are taken by other Government agencies. Consideration has been given to the need to adopt consistent measures for all activities that have the potential to affect the closed seamounts. It is clearly inequitable for one sector, such as fishing, to be denied access but for another, such as mining, to continue to have access and thereby adversely affect the closed seamount.

Way forward

An initial step has been made in New Zealand to address the impacts of fishing on seamounts. Some of the key challenges are still to be resolved.

There is an underlying tension between the growing public sentiments in favour of environmental protection and the ability to provide certainty relating to investment in property rights and fisheries infrastructure. A greater level of agreement or common understanding of all participants is required about the questions to be addressed, the information required, and the measures to be implemented. The fishing industry is looking for certainty, but it is not clear whether the outcomes can be defined with sufficient clarity at this time.

There is a question about the ability of science to deliver the information or answers sought by fisheries and environmental managers. Industry has also raised a concern about the potential "capture" of the process by research providers with vested interest in maintaining a seamount research industry. There is a potential trade-off: higher costs of on-going research with fewer closed areas (but potentially more in future as a result of the information gained) *versus* acceptance of specific management of some areas with limited research costs. There is uncertainty about what the outcomes of the research may be. A limited research programme may produce skewed results upon which to base management actions.

The relative contribution by the Government or the fishing industry to funding of seamount research has also yet to resolved. The cost of a large proportion of fisheries research in New Zealand is recovered from the fishing industry.

However, with seamounts, some of the research relates to the impacts of fishing while other projects serve a wider public interest of increasing knowledge about seamounts.

The ability to create a "win–win" situation is essential to ensuring greater acceptance of management decisions. There are clear economic benefits of marketing produce from fisheries that maintain sustainable stocks and effectively address the environmental impacts of fishing.

The management of seamounts is acting as a test case in New Zealand of how the environmental impacts of fishing can be addressed in a way that meets different and sometimes competing objectives. The way forward is likely to be challenging but not insurmountable.

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THEME SUMMARIES AND CLOSING ADDRESS

THEME 1: TREVOR WARD (on behalf of Elliott Norse)

When I was asked to provide impressions on Theme 1, I realized that I hadn't been to all the Theme 1 talks. Thus this will be my personal interpretation of the talks I have been to and discussions that I have heard in the halls and the corridors - which actually might be a little more useful. I just have five points I want to make very quickly and I will talk in very general terms.

The first point is that I have heard an awful lot here about what I call, and what other people had called, 'partnerships'. Words like stakeholder, participation, ownership, objectives, outcomes and performance. For some of you they are just average 'run of the mill' words which we use every day. For others, I know, this is new territory, but I think very important for all of us.

The second point is that we've heard a lot about the need for better empirical evidence of the benefits, but less about the need for better empirical evidence regarding the costs. But this is required to empower an engagement to help to resolve the issues, and to reach more broadly agreed positions across government, industry, NGO's, public, stakeholders, etc. This is needed to deliver outcomes that are lasting and sustainable.

Third point - community expectations are definitely changing. They are not just changing in a few green groups or even as a result of a few green groups, the community is changing as well. These community expectations are also demanding, apparently quite broadly across Australia, engagement at the local community level. I know that this is happening in Western Australia and I believe elsewhere as well.

Fourth point - overall there has been a reasonably measured support, from across a broad range of people and interests here, for the concept of proceeding to think about the possibility of protected areas within fisheries management systems. It is not universally supported but broadly there has been a degree of support. The interesting thing for me is that I have heard all this before but what is very important about this Congress is that it is being said by a whole range of new and different people, not least of whom was Wendy Craik from the Australian Fisheries Management Authority.

My last point is about science, information and data. We definitely need better information, better science, and better data, and across a range of disciplines by the way, including ecology, biology, socio-economics and a lot more. This should be innovative and we have seen some examples of how it can be done. But equally we have heard arguments that we can proceed now, that we don't need to wait for additional information, and these should go along hand in hand. Basically we know how to proceed, we have models for the process, and we also have quite a lot of existing knowledge and data. But, I would argue, we do not yet have the precise specifications of the no-take, or reserve network or system that will achieve the goals and outcomes we might all want. This is something that will be delivered from a carefully structured, broadly based, comprehensive and inclusive process that is indeed fully participatory. Yes, this will cost us, but this is an opportunity to secure some lasting solutions to some of these very important questions.

THEME 2: TUNDI AGARDY

I like others have been jumping around and didn't stick to Theme 2 talks but I have got a lot of out of what I have heard. I thought this Congress was very stimulating and I think made great leaps in certain areas. I also have five major points that I have pulled out of both the presentations and the conversations that I have heard and from some of the abstracts.

The first one is that objectives are the key. I think I heard that throughout. They vary enormously and that they must be specifically stated. We heard this time and time again. Theme 2, of course, had to do with the design and selection of aquatic protected areas. So objectives are important; what kind of design is going to be employed to meet particular objectives?

The second key point that seemed to be a key motif throughout many of the talks was that terminology is, in fact, very important. It's not just semantics, it is crucial to be clear. We need to get, if not consensus, then at least we need to put an additional investment of energy and resources into articulating clearly what we mean when we say a marine reserve or a sanctuary, or a marine protected area. Related to this is that communications are even more essential than just getting the terms right. We need to be thinking of not only how we are clear among ourselves but, even more importantly, how is that resonating with the public, if at all. Can they understand us when we talk about no-take reserves or multiple-use, or differing objectives? Part of this is that you really need to know your stakeholders. Not only do you have to identify your stakeholders, you have to understand the language they speak and try to speak to them in that language.

The third point that I gained from several talks was that modelling and theoretical approaches can be very useful but at the same time ground truthing is equally valuable. It is fine to think through MPA design on a theoretical level but it is extremely important to go out and do a reality check and test to see that models are applicable in real situations. Related to this of course is the idea of adaptive management in the strictest sense of the term. You can use a marine protected area design to gain more information and in order to do that, it is imperative to set up true experiments.

The fourth point is probably the principal one and it kept coming up in many of the talks: the idea of connectivity and linkages, both across ecosystems and also across human systems. It seems that people are starting to think big across whole ecosystems, whether it is across whole bioregions or whether it is incorporating freshwater and marine linkages into the planning process. Many presenters talked about the necessity of protecting linked habitats and using a mosaic-like approach and of course a natural outcome of that is to look at MPA networks of various types and see if the protection can be spread across linkages in order to conserve the whole.

The last point major point is that it is very important to systematically organize our knowledge about marine protected areas and their uses before we design them. Several authors mentioned classifications systems and the importance of recognizing uncertainties. A wholly *ad hoc* approach is not an effective approach but at the same time we need to be flexible. Many people mentioned the need for adaptive management to amend our MPAs as we gain more information. The world is constantly changing and marine protective areas systems should be as dynamic as our natural systems are.

THEME 3: BILLY CAUSEY

I found that the presentations throughout were of a high quality, provided excellent information and there was an enormous opportunity to have a dialogue about this very important topic of aquatic protected areas.

One of the things that I was gratified to see early on was an attempt to define marine protected areas and establish a clear understanding that when we are talking about marine protected areas we're not necessarily talking about no-take areas. Marine protected areas are a tool that can help us manage resources, whether they are fully protected or not. In the United States we have seen a tremendous effort to try to separate the two. Right now, when you use MPA in some audiences, it's tended to be received very negatively when in fact it is a very positive concept.

Throughout Theme 3, I heard planning was one of the key points. I heard some good papers that talked about various efforts that are undertaken to plan reserves and the strategic placement of reserves. We heard about the new tools for marine protected areas and marine reserves, about modelling and the new technology that are important for establishing and siting reserves.

We also heard a lot about State and Federal challenges and governmental activities. I think there was this underlying point that sometimes we tend to think of our own agency only when in fact all agencies together could form a formidable alliance. This is not an issue that is uncommon in other areas. It is one of the toughest issues we deal with in the United States.

I heard a lot about the importance of using good science. I heard a lot about the natural sciences, but it was gratifying to hear some talking about the social sciences. The natural sciences can tell us where to site reserves, for example, but if you don't have the social sciences backing it up, then you are going to have failure. I heard about stakeholder participation and advisory groups, and that was exciting. I listened to a presentation about the advisory groups in New Zealand and how effective or not effective they are in some instances and the reasons why they were effective. Excellent presentations like that make us realize that we just can't form a group and call them advisory. We need to understand why it is or is not functioning.

Throughout the last few days one of the most exciting things, not only just in Theme 3, was the number of young people presenting. The young people that are going to be stepping in the footprints right behind us as we leave this great career and background that we are in.

We heard about some of the trends and planning for marine protected areas. Trends such as greater involvement of stakeholders at all levels and also that governments are starting to invest more and take it seriously when they say they are valuing stakeholder input.

We are also hearing that there are some new concepts such as compensating fisherman for reduced catches in MPAs. That was brought up in one of the last sessions, and yes, it has already been considered in some areas but it is a trend that is being picked up elsewhere. Technology also has an important role in helping us site reserves.

This brings me to one thing that we learned today. We have to be truly honest with our science regarding whether reserves are working or not. I heard an excellent paper this afternoon where for this particular species, rock lobster, it doesn't appear that reserves are helping. As a manager, I don't see that as a reason as not to pursue reserves but I see it as a reason to make sure all the tools in place when we get ready to site them.

THEME 4: JON DAY

Many of the points made by the previous speakers were also apparent in Theme 4. There were about 24 papers in Theme 4 and they were all supportive of this need for evaluating performance. The sort of things that we heard quite a bit throughout was the importance of getting the community involved with evaluation and the benefits for all of us of this. The value of long-term time series data, the real need for information for proper decision-making and the value of this sort of data not only for the decision makers but also for the wider community and other stakeholders.

We heard about the advantages of using models to help assist in the assessment of various options. Some of the most exciting stuff was some of the innovative ways of undertaking monitoring. The benefits of new technology and new techniques for not only the evaluation but the ongoing scientific benefits, workplace health and safety benefits were apparent.

We heard a lot about the need to expand our knowledge. Obviously this is a critical role of resource management when we have such a limited knowledge of what we are dealing with out there. Throughout we heard a widespread recognition that what we have to do is monitor and evaluate. However, lessons that I think came out repeatedly throughout the papers in Theme 4 are more in the socio-economic area and the importance of this information for sound decision making: the need to communicate in a simple form that can be understood by the wider community and our political masters.

We heard the obvious reasons why we had to do this to get the support we needed for what we are trying to do. There was the more fundamental requirement to more clearly articulate our objectives and the key management issues that we have and to put them into priority order. The issue is that we have to make decisions without having perfect knowledge: that is the precautionary principle that was brought out in a number of papers. We certainly need good science and we certainly need good knowledge but we can't always afford to wait to have the perfect answers. We heard the need to think big and think outside the square. We can have the best MPA system and we can have the best evaluation system. However, so much depends on areas that are beyond our control and jurisdiction. This whole idea of thinking big in an ecosystem manner came through in quite a few of the papers.

Lastly we also heard the need to practice what we preach. It's all very well to be evaluating other people but we need to evaluate ourselves within our own agencies. In summary that there was widespread recognition and agreement about the need for evaluation and measuring performance but I think pretty clearly that we have a long way to go.

THEME 5: JOHN KOEHN (on behalf of Peter Cullen)

This Theme was on the role of aquatic protected areas in the aquatic ecosystem. The interesting thing about this Theme was that this was where most of the freshwater papers ended up and there was a fair balance between marine and freshwater papers. There were quite a few differences and it seems as these two areas are in very different stages of development. Most of the marine was international, and most of the freshwater was Australian. As Peter Cullen touched on in his Keynote Presentation this morning, in freshwater, there are a lot of lessons that can be learnt.

A topic throughout this Theme was the need to deal with issues outside the aquatic protected area, to extend the vision and the management beyond the actual APA zone. These varied from larger issues like taking into account the global climate change to more local ones. Along with this was the idea of looking more at ecological process and community interactions. I guess this reflects the state of management maturing to that level of complexity. I think that is very beneficial.

In terms of marine APAs they are generally larger, and the Great Barrier Reef Marine Park is obviously testament to that. They are generally more established and generally more supported and this wasn't so in the freshwater area. It is probably because the situation in freshwater is where the marine parks were quite some time ago. During some of the papers and in some of the discussions, a few bristles were raised. In freshwater, whether protected areas would be good or bad is probably part of the debate that the marine community had quite some time ago. There was also quite a lot of discussion about community involvement and ownership of issues and their effects on the reserve systems. We heard about the legal and treaty obligations and whether or not they had been enacted upon.

One thing that I noticed that we didn't hear much about is what reserves achieve socially. We heard about the dollars or the fish they protect but we didn't hear anything about, at least I didn't hear anything about, why we really want them and what they do for community well-being and why in our psyche we feel closely aligned to these reserves.

There were some words from Peter Cullen near the end of his presentation that summed up, in a few short points, things that were important. These were protection is cheaper then restoration, you need to think big, you need to act now, you need stakeholder support, and you need funding. I think these points are demonstrated by successes such as the Great Barrier Reef Marine Park, but these still need to be done in a whole lot of other areas.

CLOSING ADDRESS

The Honourable Dr Virginia Chadwick, Chair, Great Barrier Reef Marine Park Authority.

Delegates, I would have to say that I was hanging on to Keith Sainsbury's last words because he and I had the somewhat doubtful pleasure of sitting through those painful UN processes. I fronted up the next year which shows that I have greater fortitude than you do Keith. We are still moving at glacier pace but I am pleased to say that it is an inch at a time in the right direction. So perhaps there is some reason for optimism and hope. Can I say thank you very much to the organizers for deciding to hold this Congress now and here and I say that somewhat selfishly as part of the Great Barrier Reef Marine Park Authority.

In terms of NOW we have closed our eyes and jumped. We have just completed the first community participation phase of our Representative Areas Program. This is aimed at significantly increasing the highly protected areas within the Great Barrier Reef Marine Park. So it is timely and heartening for all of us here to see so many people interested, and all of those who have said kind and encouraging words about the Marine Park Authority. This is very much welcomed and timely because after 200 meetings and 10,000 submissions, and still counting, some of us are feeling a little bruised. Can I also say that it is geographically apt that you're here right on the doorstep of the largest marine protected area and the largest world heritage site. It has provided so many of us with an opportunity to come up from the Authority and to join in the working of the Congress.

So many of us are here from different perspectives; whether we're scientists, experts, or people like me, who regard themselves as managers, and also whether one is from a freshwater or marine perspective. I believe this is a sign of increasing maturity in the protected areas debate and I hope, like me, you found it encouraging.

I come here as a manager, a manager with dual roles, some would say a conflicting role, because it is our job to conserve and protect for current and future generations the values of the Great Barrier Reef Marine Park. It is equally our legislative duty to ensure that in so doing we allow for reasonable use and access to a wide variety of uses, both recreational and commercial. This is the nub of management. Whether areas are as large as the GBR or smaller, whether they be for multi-use or single use, it is to actually strike that balance. It would seem to me that we have done a fair job in the last few days of giving a good interpretation of some of these challenges and I think providing guideposts of how to mesh these needs and how to move forward.

In our case, over 25 years now, we have used particular tools. Blunt tools such as zoning, finer tools, such as plans of management, and even finer tools again, such as rules in relation to particular settings. What I do think might be timely, given so many people have talked about pressures on both the marine and freshwater environment, is to think back over that quarter of a century and ask ourselves why was the Marine Park Authority formed in the first place. Depending on whether on you are by nature pessimistic or optimistic, it is either a course of joy or despair. If you think back 25 years ago, people were concerned about water quality, run off from the land, crown-of-thorns starfish plagues, shipping traffic, and the sustainability of fishing. People were also concerned about the coral reefs *per se*, particularly as some were regarded as dead and being mined for fertilizers or for building blocks.

Now some of those pressures are gone but it is interesting when you think back over these events. As an optimist, however, I believe our response and our understanding have improved dramatically. I was heartened by the advice to think from an ecosystem perspective. The one thing that we are trying to do through our Representative Areas Program is to think from this perspective. At this Congress, we were advised to be very clear about our objectives. It is very important and it was raised by a number of the panellists in their summing-up. I think it was also good advice to be told to stop using acronyms wherever possible and to communicate one's objective as clearly, as honestly and as simply as possible. I think that has struck a chord with so many of us at the Congress.

In terms of our Representatives Areas Program, we are clearly saying that we are approaching this from a conservation viewpoint. Many people, in recent months have tried to draw us into a debate about MPAs as a fisheries management tool. That is not our aim and it would be most unwise and untruthful to say otherwise. I don't think that we should be drawn into suggesting that protected areas are some form of silver bullet. Equally the comment made by so many presenters that one size does not fit all was timely advice. What it did bring home to me, and I am sure to many other delegates, is the importance of realizing that a protected area is simply one part of the jigsaw. It is a tool, and a necessary tool. But it is not a silver bullet and it will not conserve, in my view, a marine or freshwater environment, unless it is part of a suite of other tools. An important one, of course, has to be fisheries management. Now, I say that, particularly given recent activities in the area of the Great Barrier Reef. We are hoping that within a matter of weeks a draft management plan on reef line fishing will have been released for public comment. We have been waiting for this for a long time; it is a difficult and contentious area. The plan will be released by the Queensland Fisheries Service.

In the course of the consultation that has been involved in the Representative Areas Program, a number of people have said to me "Ah, this makes for double jeopardy". Fisheries are going to be challenged by the Representative Areas Program and then they are going to be further challenged or put in jeopardy because of a new fisheries management plan. I do believe there is a possibility for double jeopardy but I see it in completely the reverse terms. If we do not get on with it and find some resolution to the very difficult and vexing questions of reef line fishing, then that fishery is itself in jeopardy. I also believe that without the Representative Areas Program, the fishery is in jeopardy in the longer term. Hence while I would agree with terms such as double jeopardy but from a completely different perspective.

In terms of realizing that protected areas are not the silver bullet for conservation and the marine environment, we have to look at the issue of water quality. Again in terms of the timeliness of this Congress, I think it is important to remember that it was earlier in this week that the Prime Minister of Australia and the Premier of Queensland agreed upon a Memorandum of Understanding between the Commonwealth and the State. A commitment was given to the production of a plan by the end of the year to address issues relating to water quality particularly as they impact on the Great Barrier Reef. So I think at Government levels there is increasing recognition of the inter-connectivity of aquatic environments and also the necessity for collaboration between agencies and management.

During the Congress, people have spoken a lot about monitoring. I agree with much that has been said and would reinforce that the GBRMPA is taking monitoring seriously and we should. We also have to be able to admit up front and openly when we need to adjust, when we have made a mistake, and when our best judgment hasn't been good enough. This is going to need a lot more maturity from managers and agencies.

One issue that has been touched upon, but I don't think has had the importance that it deserves, is compliance. I am one who strongly believes that there is no point in drawing a line on a map if you don't intend to enforce the rules that you have made. So it puts a greater importance, a greater duty on us all, to make sure that we have the resources not only to get on with the job, not only to monitor, but also to ensure that compliance is undertaken as well.

Can I just briefly touch upon the issue of consultation? Much has been said about that and I agree with the overwhelming weight of comment at this Congress. If you can't take your communities with you, and you can't speak the same language as the groups with whom you are trying to build partnerships, then everything is fraught with difficulty. I must say that I was particularly taken with the notion that scientists are another group of stakeholders and I look forward to future discussions with scientists in that regard. I was heartened, however, given my particular background, with the emphasis that people are placing on social sciences, and in particular, economics. I think it is going to be the balance between science and economics, and peoples needs and uses that are going to be so important in the future. In terms of understanding needs, the importance, particularly in an Australian context, of indigenous engagement is something that we are all going to have to focus on. I think there is still much that we need to learn in this area.

Can I just finally say, however, that no matter how long we consult, how much science is done, how much thinking we need to do, and no matter how much we build towards consensus, at the end of the day, someone is going to have to make a decision. Otherwise, we're going to be at the next Congress talking once again about designs and about various aspects of Aquatic Protected Areas. That is why, at the end of the day, leadership is extraordinarily important. To get leadership one needs to communicate not just with the community but also with our masters, our funding agencies and our supporters. It's the type of leadership that actually leads to the formation of the marine park authority. It is going to be that conjunction of groups, political and community, that is going to drive not only the representative area forward but it is going to drive all aquatic protected areas forward. Thank You.

John Glaister, Congress Chair

Thank you very much Virginia. It now just requires me to wind up. I won't go through a lot of thank you's but I want to acknowledge our sponsors again. The Australian Society for Fish Biology took on the task of hosting this Congress, it was a task that its members did willingly and I think that the benefits to members and the exposure to new groups has been mutually beneficial.

I would also like to acknowledge Peter Dundas-Smith and the Board of the FRDC. The FRDC has been a strong supporter of this Society but I think more importantly, Peter, has been a real supporter of research and particularly young research. So we appreciate your support on this occasion and I think that it has been a good investment.

We also have a number of other Commonwealth and State agencies as important sponsors. I would particularly like to thank NORMAC, (the Northern Prawn Fishery Management Advisory Committee). It is always daunting for user groups to come in and participate in such a debate and I think that NORMAC and the industry representatives that are here deserve a great deal of credit.

POSTER PRESENTATIONS

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THEME 1

Presenter	Title
Dong Chun Lou, CRC Reef Research Centre, AUSTRALIA	Effects of Aquatic Protection Areas on the Age Structure of Common Coral Trout (*Plectropomus leopardus*) in the Great Barrier Reef World Heritage Area of Australia
Kim Nardi, Department of Fisheries Western Australia, AUSTRALIA	Contrasting Effects of Marine Protected Areas on the Abundance of Two Exploited Reef Fishes at the Sub-Tropical Hourman Abrolhos Islands, Western Australia
Douglas Nicol, Marine Resources Group, AUSTRALIA	Why Should We be Able to Kill Fish Everywhere?

THEME 2

Presenter	Title
Simon Banks, New South Wales National Parks & Wildlife Service, AUSTRALIA	Intertidal Habitat Classification and the Identification of a Network of Aquatic Protected Areas
Suzanne Pillans, University of Queensland, AUSTRALIA	Effectiveness of No-Take Marine Reserves in Subtropical Queensland, Australia
Scott McKinnon, Queensland Fisheries Service, AUSTRALIA	Selection and Assessment Criteria for Fish Habitat Areas in Queensland, Australia
Simon Bryars, Primary Industries and Resources, AUSTRALIA	An Inventory of Important Coastal Fisheries Habitats in South Australia
Andrew Read, New South Wales Fisheries, AUSTRALIA	Establishing a Representative System of Marine Protected Areas in New South Wales, Australia
Patricia Carvalho, Department for Environment and Heritage, AUSTRALIA	Principles and Methods used to Identify a Bioregional System of Marine Protected Areas in South Australia
James Larcombe, Bureau of Rural Sciences, AUSTRALIA	Mapping Commercial Marine Fisheries and Their Resource Dependant Coastal Communities, South-Eastern Australia
Jane Jelbart, University of Western Sydney, AUSTRALIA	Designing Protected Areas for Small Fish in the *Zostera* Seagrass Beds of an Estuary: What Features Matter?
Christina de Vries, Queensland Fisheries Service, AUSTRALIA	Remote-Sensing and GIS Technologies - Supporting the Protection of Representative Fish Habitats in Queensland

THEME 3

Presenter	Title
Rebecca Sheppard, Queensland Fisheries Service, AUSTRALIA	The Trinity Inlet Fish Habitat Area – Declaration and Management
Rodney James, New South Wales Parks & Wildlife Service, AUSTRALIA	Marine Protected Areas in New South Wales National Parks - Inventory and Role in Marine Conservation
Colin Chalmers, Department of Fisheries Western Australia, AUSTRALIA	Declaration And Management of The Abrolhos Islands Fish Habitat Protection Area
Scott McKinnon, Queensland Fisheries Service, AUSTRALIA	The Fish Habitat Area Network in Queensland, Australia - An Innovative Aquatic Protected Area Approach
Karen Edyvane, Department of Primary Industries, Water and Environment, AUSTRALIA	Planning a Comprehensive, Adequate and Representative System of Marine Protected Areas in Tasmania
Libby Sterling, NSW Marine Parks Authority, AUSTRALIA	Consultation with Aboriginal People for Planning and Management of Multiple-Use Marine Parks in New South Wales, Australia - a Case Study - Solitary Islands Marine Park
Quentin Hanich, Greenpeace Australia Pacific/Antarctic and Southern Coalition (ASOC), AUSTRALIA	Failures and Opportunities - Marine Protected Areas and Antarctica
Simon O'Donnell, Department of Natural Resources and Mines, AUSTRALIA	Natural Resource Management Community Groups in the Wet Tropics
Geoff Dews, AMSAT Pty Ltd, REPUBLIC OF MALDIVES	Elements of a Marine Protected Area in a Small Island Developing State - Republic of Maldives
Peter Long, Queensland Fisheries Service, AUSTRALIA	Calliope Fish Habitat Proposal - A Case Study
Sabine Jessen, Canadian Parks and Wilderness Society – British Columbia Chapter, CANADA	Baja California to Bering Sea Marine Conservation Initiative: An Example of Tri-national Cooperation on Marine Protected Areas
Carl M. Stepath, James Cook University, AUSTRALIA	Environmental Education and Participatory Action in the Tropical Marine Environment
Damien Burrows, Australian Centre For Tropical Freshwater Research, AUSTRALIA	Managing the Spread of Translocated Native Fish into Aquatic Protected Areas in Queensland

Presenter	Title
Colton Nicholas Perna, Australian Centre for Tropical Freshwater Research, AUSTRALIA	Improving Fish Habitat Upstream of an Aquatic Protected Area, Bowling Green Bay, North Queensland.
Martin Russell, Great Barrier Reef Marine Park Authority, AUSTRALIA	First Define Your Closure Objectives - Easier Said than Done!
Malcolm Turner, Day-To-Day Management Coordination Unit, Marine Parks, AUSTRALIA	A Whodunnit – How Necropsies of Dugongs, Turtles and Cetaceans Lead to Better Marine Wildlife Management in the Great Barrier Reef World Heritage Area
Peter Clifford, TerraVision Pty Ltd, AUSTRALIA	A Real-Time Statistical Modelling System using Catch Data and Vessel Moitoring System (VMS) Data Applied to a Scallop Fishery
Jos Hill, James Cook University, AUSTRALIA	Minimising Inter-Observer Error for Reef Check Benthos Training. A Case Study on the Great Barrier Reef.
THEME 4	
Karen Rudkin, Griffith University Gold Coast, AUSTRALIA	A Preliminary Assessment of Two North Queensland Estuaries Containing 'No-Take' Fish Reserves: Quantifying the Variability in Relative Abundance and Length Distributions of Target Species
Cristiana Damiano, UFPE, BRAZIL	One Year Assessment of the Health of Coral and Fish Assemblages in the National Marine Park of Fernando de Noronha, PE, Brazil
Nathan Waltham, Gold Coast City Council, AUSTRALIA	Using Catchment Wide Investing Catchment Wide Investigations to Evaluate and Target the Management of Coombabah Lake: an Aquatic Protected Area
Nick Ellis, CSIRO Marine and Research, AUSTRALIA	Modelling Trawl Impact on the Benthic Biota in the Great Barrier Reef Region
THEME 5	
Andrew Page, Environmental Protection Agency, AUSTRALIA	Assessing the Conservation Values of Queensland Estuaries for the Purposes of Marine Park Planning and Review
Kirstin Dobbs, Great Barrier Reef Marine Park Authority, AUSTRALIA	Marine Mammal and Turtle Strandings in the Great Barrier Reef World Heritage Area