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Assessing Recreational Fisheries – Current and Future Challenges

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Assessing Recreational Fisheries – Current and Future Challenges

Edited by James P. Scandol, Charles A. Gray, Aldo S. Steffe and Douglas J. Ferrell

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Bob Kearney (Session One)

Richard Stevens (Session Four)

President's Foreword

The Australian Society for Fish Biology was formed in 1971 by 79 members. For three decades, the ASFB conferences and workshops have helped to advance fisheries and aquatic science by providing new information for the conservation of biodiversity and sustainability of natural resources. With the support of our major sponsors, the ASFB workshops have played a key role in addressing the national priorities and issues for research and management. The 2008 workshop theme "Recreational Fisheries Assessment – Integrating Science and Management" is a fine example as it brought together scientists, managers and recreational fishing representatives from Australia, New Zealand and USA to exchange and review different approaches to recreational fishery monitoring, research and management. The workshop was timely, as it followed the first National Recreational and Indigenous Fishing Survey (NRIFS 2000-01) reported by Henry and Lyle (2003). This survey largely answered the question "Recreational fishing: what's the catch?" that was posed by the 1994 ASFB Workshop held in Canberra. With the recognition of the number of Australian anglers, the quantity of fish and their expenditure in 2000-01, more questions are now being asked. There is an increasing demand for more information on the recreational fisheries to improve management strategies and ensure a sustainable harvest.

In the face of shrinking research budgets and increasing pressure on fisheries, the need to cooperate and share information is crucial. Robust scientific methods, evaluation, validation and innovative solutions are just some of the topics that were discussed at this workshop. The last session "What should sustainable recreational fisheries look like in 20 years?" provided a vision of the future stakeholder expectations and research needs.

As recreational fisheries management is becoming increasingly more sophisticated, so the science and research underpinning management must also advance and Australian fisheries researchers have been at the forefront of developing better monitoring techniques that are cost effective and statistically robust.

Approximately 90 delegates attended the workshop, including a large number of students; the future of fisheries science. The benefits of scientific networking and opportunities for professional development at ASFB workshops are realised through enhanced collaboration, the uptake of new techniques and the application of new information. At this workshop, the organising committee assembled an outstanding program of 31 international and national presenters covering four themes:

- Review of recreational fisheries research and management in Australia, New Zealand and the USA.
- Aquatic resource management and recreational fisheries research strategies with a plan to address the national data requirements.
- Recreational fisheries research methods in Australia, New Zealand and the USA.
- Recreational Fisheries Research and Management in 2028.

I would like to thank all our speakers and particularly our international speakers Martin Cryer (New Zealand Ministry of Fisheries), Bruce Hartill (NIWA), and Sandra Diamond (Texas University and University of Western Sydney) for sharing their information and views. The approaches adopted in other countries offer important lessons that will help to improve recreational fisheries monitoring and assessment. I am very grateful to the convenors of each session : Bob Kearney, James Scandol, Aldo Steffe, and Richard Stevens. The 2008 organising committee, led by James Scandol and Aldo Steffe, did a magnificent job in ensuring the workshop ran smoothly and I am sure that all delegates will have emerged from the workshop with some new ideas for future studies and collaboration.

The workshop outcomes have a major influence on fisheries science and management. The proceedings of many previous workshops, which are now freely available to the public on the website (www.asfb.org.au), document the history of the achievements of our Society. These proceedings offer the latest techniques and a new vision for the future, providing guidance to everyone with an interest in recreational fisheries.

The workshop series is reliant on the support of corporate and agency sponsors and I thank the Fisheries Research and Development Corporation for their continued support of the ASFB workshops. FRDC was again the Principal Sponsor for the 2008 workshop, and NSW DPI was the Principal Sponsor of the conference.

Patrick Coutin

President

Australian Society for Fish Biology

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The Australian Society for Fish Biology Workshop 2008

Assessing Recreational Fisheries Current and Future Challenges

Why, Who, What and How? Key Questions about the Assessment of Recreational Fisheries in Australia

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Background

This essay provides an introduction to the 2008 Australian Society for Fish Biology Workshop "Assessing Recreational Fisheries – Current and Future Challenges". The aim is to present a broad picture of the underlying issues that were discussed on the 16th September 2008. By presenting a general overview of the recreational fishery monitoring, assessment and management issues raised, it is hoped to clarify some of the needs and desires of stakeholders, policy and management options available to governments, and the capacity of scientists to obtain and provide required information. All three of these groups were represented at the 2008 ASFB Workshop, but the foundation for, and context of, a lot of the comments, positions and assumptions made at the workshop were often somewhat opaque. Several workshop attendees commented to the organising committee that it was hard to "see the wood for the trees" and asked where was the "big picture". This essay attempts to paint that big picture and indicate parts of that canvas that were not clear from that day.

Why Assess Recreational Fisheries?

The theme for the workshop begged one very important question – *why* monitor and assess recreational fisheries? From a definitional standpoint, when we "assess" something we estimate one or more dimensions or characteristics such as it's size, complexity, durability, impact or value. However, to be useful, the assessment must have a purpose or aim. The nature of estimation is such that assumptions are inevitably made, and these are dependant upon the context of the problem.

The ownership of wild fishery resources has an interesting history, but very simply, private ownership of fish resources in public waters was prevented under common law (in countries with British-based legal systems such as Australia, Canada and the United States). Such resources could therefore be taken by any member of the public as they chose and could therefore easily be subject to the "tragedy of the commons" (Hardin 1968). To avoid this outcome, governments have progressively moved to vest ownership of aquatic resources to the Crown. Therefore, although the public has common law rights to fisheries resources, they only do so if the government has not removed these

rights via environmental or other statutes (Bates 2002). Legal instruments such as legislation and regulations define the conditions of access to these resources (also see Gullett 2008).

Government therefore plays a key role in managing access to and controlling use of common pool fisheries resources – much more so than most other areas of natural resource management. There will, however, always be a fundamental tension between the perceived right of various community sectors to obtain access to these common pool fish resources, and the government's obligation to manage that access and use in order to maintain current and future public benefits. Such relationships between the public and government are complex; and there is a significant body of both common and statutory law that defines the legal framework that determines the relationship between the government and the governed (Douglas and Jones 1999). This framework includes concepts such as procedural fairness, reasonableness and standards of evidence. Government administrators may have their decisions appealed if they have exceeded their statutory powers or have not adhered to the procedures required (Douglas and Jones 1999).

This relationship between the government and the community places two fundamental responsibilities on government when managing aquatic natural resources and the ecosystems that support them. Firstly, governments must capture the broader community views and values on how these aquatic resources and ecosystems should be managed now and into the future, and to present a transparent "road map" of policies, strategies and specific actions so that the public understands what the government is trying to do, and the reasoning behind the approach. Secondly, given such plans will inevitably compromise the access and use wishes of some individuals, governments must provide a credible justification for strategies and management actions being applied. These issues are common in all areas of environmental management, and the primary strategy used by governments is some type of environmental planning instrument (for example May *et al.* 1996).

There is thus a need for linkages between planning processes and the application of evidence-based management strategies. A connection should exist between the strategies of government for managing access to, and use of, common pool aquatic natural resources, and the information or evidence to justify and support such management actions. In the case of fisheries, almost all of this information comes from some type of assessment of fish stocks and habitats, fishing activities or the values and attitudes of fishers.

Fisheries Management Plans and Fisheries Assessments

Environmental (or natural resource) management plans have been defined as a government plan for the management of a resource based upon a scientific evaluation of its sustainability (Bates *et al.* 1997). Fishery management plans usually include management objectives for the resource, a list of fish stocks and fishing activities covered by the plan, an identification of the key stakeholders, information about the access and harvest rights, and measures to protect fish stocks, habitats, non-retained species and ecological processes from the impacts of fishing. Performance indicators are also included to measure the implementation success of the plan. Public consultation is a key feature of the development or review of a management plan to ensure that interested parties have an opportunity to participate in the decision-making process. Management plans or arrangements for Commonwealth fisheries and all export-orientated commercial fisheries in Australia are subject to

strategic environmental assessment under the Commonwealth's *Environmental Protection and Biodiversity Conservation Act* (1999). Formal management plans have also been developed for other state-based commercial fisheries under state fisheries legislation.

To date, however, management plans for recreational fisheries have generally been less subject to formal development and review processes. Some recent examples of formal development or review processes of recreational fishery management include plans for three Gippsland estuaries in Victoria (Fisheries Victoria 2006; Fisheries Victoria 2007), the Lakes and Coorong Fishery in SA (Sloan 2005), the Houtman Abrolos System in WA (Department of Fisheries WA 2007), and the recreational fisheries components of management plans for fisheries where stocks are shared between competing sectors (e.g. the Queensland Inshore Fin Fish Management Plan which is under development). Plenty of other examples could be identified from Australia, the United States and New Zealand.

The process of developing or reviewing a management plan forces deliberation about the nature of evidence-based performance management. Achievement of good governance practices will generally require that management planners try to move away from general statements such as "fisheries should be sustainable" to specific goals and targets with defined performance indicators and reference points. This requires consideration of what is actually measurable given the nature of the fishery and the resources that will likely be available to implement the management plan. Thus a dialogue must be established between the management planning community (responsible for developing and implementing management plans) and the fishery assessment professionals (responsible for providing biological, economic and social information to underpin assessments). Furthermore, their plans to manage a fishery and the performance assessment of that plan must be open to public scrutiny.

Who should be involved in assessing recreational fisheries?

Before tackling the challenge of what needs to be assessed to facilitate management of recreational fisheries, and how such assessments should be done, consider the three major players in this debate: fishery (or environmental) managers; fishery scientists (including environmental scientists, biological scientists, economists and social scientists) and stakeholders (including the recreational and commercial fishing interest groups – including seafood consumers; Indigenous and traditional fishing interests; and other non-fishing interest groups including the members from the conservation movement).

As indicated above, the conduct of assessments is fundamental to good decision making and accountability in the implementation of management plans, but this can present formidable challenges. The first challenge is to identify the most appropriate types of monitoring and assessment needed to address important environmental, biological, economic or social objectives identified in the management plan for a given fishery. The type and quantity of information collected and the type of assessment method used will depend on the characteristics of the fishery (including its size, profile and values) and the type of management objective the assessment is designed to address.

Having identified the assessments needed for a particular fishery, the next challenge is to determine the most cost-effective way to carry out these assessments. One solution is to pass responsibility for the conduct of monitoring and assessment programs (which may include biological, ecological, economic and social components) to independent professionals who will collect, analyse and report on agreed performance indicators. However, in all but the simplest systems (such as large high-value commercial fisheries), such an approach will be prohibitively expensive. There will also likely be protracted debate about who is responsible for this cost. The inevitable strategy that is reached in almost all types of aquatic natural resource management is to involve key stakeholders (such as commercial and recreational fishers) where possible in the collection of information to facilitate performance assessment. This is done not only to reduce the costs of the performance assessment, but to engage stakeholders in the performance management system itself.

Deciding whether or not to involve stakeholders in fishery monitoring and assessment programs is a balancing act. If stakeholder-collected data doesn't have credibility in the eyes of the general public, then the outcomes of the performance assessment will be compromised. If the independent collection of data becomes too costly, then the scope of the performance assessment will either become too narrow or too diffuse. These trade-offs are difficult enough to resolve in commercial fisheries, but are far more complex in recreational fisheries because of the large, dispersed and diverse nature of the recreational fishing community. These are issues that must be the subject of ongoing evaluation and testing of alternative strategies, as they won't be resolved easily.

Aquatic natural resource management is not the only issue in society where the community is actively involved in providing information on its own activities. An interesting analogy is income tax. Nobody likes paying income tax, but a large majority acknowledge it is crucial for the operation of a contemporary society. Government doesn't have the resources to monitor everyone's income, so individuals (and companies) provide assessments of their own income and the subsequent tax payable. The system is carefully balanced so the majority receive a small reward (refund) for their contribution. Government audits a small fraction of these assessments to ensure that there is acceptable compliance. An analogy to this process could be a cost-effective way of obtaining information needed for management performance assessment in some recreational fisheries.

How this self-monitoring and audit process could work would need to be determined on a case-by-case basis, and it is very likely that any system adopted would need to be reviewed and adapted regularly. There are pressures for and against stakeholder involvement in the performance assessment of management plans. If there is too much reliance on fishery–dependent data or too few audits for quality, this could lead to compromised credibility of management decisions, which will drive change for increased fishery-independent data collection or greater audit rates, with subsequently higher costs. If the performance assessment is completely fishery-independent, stakeholders may not see its relevance and it is likely to become very expensive, which will drive change for better linkages to the angling community and reduced costs.

The challenge for fishery managers is how to maximise the quality and therefore the credibility of data collection and assessment whilst simultaneously minimising the costs. This is easier said than done. Dollar costs can be measured very accurately (this is what accountants excel at), but the

concept of credibility is far more difficult to quantify (Alagona, 2008). Although some estimates of statistical precision are usually available with most data sets collected, measures of bias are not likely to be available unless there is a second independent dataset available for comparison (which there usually is not). An undesirable corollary of the data credibility issue is that the reputation of the professionals involved in the assessment is often also impugned. Cullen (2006, and references therein) noted that both the data and the reputations of scientific professionals have been challenged during the recent water allocation debate in Australia.

Independent review of the monitoring and assessment processes will make a contribution to improving the credibility of performance assessments, but if some stakeholders have very fixed views, then for them it may always be a case of "Don't confuse me with the facts, I've already made up my mind!". Recent work in behavioural psychology has shown humans can be predictably irrational (Ariely 2008), particularly in circumstances which involve information that is inconsistent with their existing beliefs. This reinforces the importance of integrating the social sciences into decision-making for fisheries management.

There were many strategies proposed at the ASFB workshop that attempted to improve the performance assessment of recreational fisheries management. Nearly all required the co-operation of recreational fishers to at least collect information. A better understanding of the role and motivations of anglers in participating in this process would be extremely beneficial.

What should be assessed in recreational fisheries?

In theory this question is perhaps the simplest to answer provided the environmental, biological, economic and social goals for the management of a particular fishery are clearly specified. If the above arguments presented about the "Why Assess Recreational Fisheries" are accepted, then it flows that the performance assessment of a management plan will be directly linked to the goals and objectives of the plan, which will in turn be directly linked to statutory obligations and policies of government.

Contemporary legislation to manage the use of aquatic natural resources in Australia is based upon principles of Ecologically Sustainable Development (ESD), which is usually realised in fisheries management agencies as giving the highest priority to the conservation or protection of the biological resource (including species, habitats and communities). Recreational and commercial access to fish resources is permitted provided such use is sustainable, and acceptable safeguards exist against any environmental impacts. Maximisation of social and economic benefits from commercial and recreational fisheries is encouraged within the limitations of sustainable overall use. For example, in NSW the aims of fisheries management are - within the limits of ecological sustainability – to promote viable commercial fishing and promote quality recreational fishing opportunities.

Such aims require performance assessment in five general areas: (i) ensuring that fishing pressure is sustainable, even for highly variable stocks; (ii) determining that the condition of habitat critical to the production of fisheries resources is not compromised; (iii) providing for resource sharing among competing fishing interests (and other community sectors) in accordance with any government

policy; (iv) measuring the economic viability of commercial fisheries and economic benefits of recreational fisheries; and (v) assessing the quality of recreational fishing opportunities. Each of these five areas will require collection of different types of information, and application of different assessment methods. Furthermore, the conduct of monitoring and assessment programs in each of these five areas will involve very different types of expertise.

For example, assessment of sustainable levels of fishing pressure requires monitoring and estimation of indicators such as stock abundance, mortality rates and recruitment patterns; assessment of the status of fish habitat requires identification of habitat essential to support production of key fisheries resources, monitoring of the extent of such habitat, and identification of any threats to the integrity of such habitat; decisions on appropriate sharing of fishing requires comparable estimates of the net economic or social value of alternative uses of the resource; assessment of the economic viability of commercial fisheries requires information on income and expenditure and on other industry conditions such as prices; assessment of the economic impact benefits of recreational or commercial fishing requires collection of information on fishing-related expenditure at various geographic scales and contributions to economic activity (such as GDP, incomes, employment); and assessment of recreational fishing opportunities will require the collection of information on the needs, attitudes, values and levels of satisfaction amongst recreational fishers.

Given that there will be limited resources for the conduct of monitoring and assessment programs, there will be pressure within each discipline to identify achievable assessment objectives (at the lowest possible cost), and to ensure that the results from the assessments are directly linked to management responses.

How should we assess recreational fisheries?

Prioritisation

In the “What” question above it was noted there are five general areas requiring some type of performance assessment in fisheries: stock status and fish habitat protection; sharing of access benefits from fish resources; economic viability (for commercial fisheries) and economic impact benefits (for recreational and commercial fisheries); and the quality of fishing opportunities (for recreational fisheries). Given that any one of these areas might easily absorb the total budget allocated for fisheries performance management then some type of prioritisation process will inevitably occur. There will simply be some fisheries, and some dimensions within a fishery, that are more important to both the government and the public to manage than others.

This prioritisation should be captured in a fishery management plan and must reflect the legislative and policy framework that gives authority to the plan, but may also reflect other more specific issues that were identified during public consultation. For example, say a particular concern was raised during consultation about discard mortality of undersized fish. A response to this will require a combination of research and management actions, followed up with a targeted performance assessment. Implementation might include monitoring of discard rates in the fishery, research on the survival of fish caught and released under different circumstances, identification of the best catching and handling practices to minimise release mortality, a public information campaign and then surveys to measure the outcomes of that campaign.

There will, however, still be tens of issues requiring performance assessment and budgets for only a handful. Moreover, the cost of any information collection program will depend in part upon the required precision of estimates and the level of biases in the data that are deemed acceptable (both of which will be difficult to quantify beforehand). There are technical tools such as cost-benefit analysis, risk assessment or multi-criteria decision analysis which could provide some guidance to identifying which aspects of performance assessment should be given priority, but given the diverse designs, outcomes and expertise required it is unlikely that any one technical model will solve this problem. The more pragmatic approach would be to identify priority dimensions of a fishery; for each priority dimension identify the most plausible and cost effective initial approach to monitoring and assessment; and then review (and if necessary revise) these monitoring and assessment approaches in conjunction with the review process of the management plan.

Credibility via Independent Review and Audit

As indicated above, many aspects of fisheries monitoring and assessment will involve a partnership between stakeholders and government. The spectrum of stakeholder involvement can vary between, at one extreme, stakeholders collecting and reporting information themselves to facilitate management decision making or, at the other extreme, stakeholders supporting the use of taxes or licence revenues to fund fishery-independent monitoring and research. The relative utility of either approach will vary depending on the type of information to be collected and the characteristics of the fishery, and for many fisheries a combination of both approaches will be required.

This article does not attempt to argue the merits of one type of monitoring and assessment approach over another, but there are two considerations which must be noted:

- In some cases (*e.g.* biological research or economic impact assessment) it will not be technically feasible or cost effective for stakeholders to collect the type of information that may be necessary to facilitate good decision-making; and,

- The more fishery assessment and management decision-making is dependent on information provided by one stakeholder group with a vested interest, the less likely are such assessments and decisions to be deemed credible by other stakeholders with opposing interests.

Performance assessment associated with the conduct of fisheries monitoring and assessment programs can be a complex process involving technical issues associated with statistical sampling, data quality control, data management, statistical analysis and reporting. Unless there are minimum standards for the conduct of these processes it is possible that there will be few valuable outcomes from any of this investment. Given that there will very likely be substantial amounts of public money involved in such projects, there has to be standards of public accountability applied to these expenditures.

The only effective strategies for dealing with such challenges are credible review processes (ideally by someone independent of the major stakeholder groups) or independent audits of the scope, implementation and outcomes of monitoring and assessment programs. These may sound like an unnecessary burden on, what will inevitably be, a resource-stretched system; but the longer term consequences of, either failing to meeting legislative objectives or expending significant amounts of

public money and time on projects which will not provide the type or quality of information needed to facilitate good decision-making, are far greater.

The ASFB Workshop on Assessing Recreational Fisheries provided numerous examples of how various government agencies were tackling the challenges associated with "How" to assess recreational fisheries.

Final Comments

In Australia, wild fish stocks are common pool resources that are widely perceived to be 'owned' by the public, and governments have statutory responsibilities to manage use of these resources on behalf of the public. If governments identify deterioration in fish stocks as a result of fishing impacts, or deterioration in fish habitats as a result of either fishing or non-fishing human impacts, then they have a responsibility to do something about it. They are obliged, on behalf of the public, to identify and reduce the human pressures that are causing that impact (or to identify public benefits elsewhere that outweigh, and therefore justify, such an impact), and to facilitate the recovery of the system to a defined condition. They must be able to measure their progress in achieving this goal; otherwise they cannot know that their strategies are effective.

Similarly, if government, on behalf of the public, has adopted a particular policy for sharing particular fish resources among user (or interest groups), they must measure their progress towards implementing this policy. If such progress cannot be assessed because the policy objectives are not clear enough, the data required for decision-making are too expensive to collect, or the science too immature, then such policies ought to be re-considered. There will be alternatives that can be assessed and the outcomes that are measurable.

The overall approach for defining and solving such problems is the fundamental challenge of environmental and natural resource management, and the key strategy used is environmental or natural resource use planning. Planning processes have a successful track record in local and regional environmental plans, water catchments, commercial fisheries, marine parks and increasingly recreational fisheries. Strategic assessments may make a valuable contribution to such plans and some type of prioritisation process (such as risk assessment) is essential to identify and progress issues.

There are a complex range of drivers for change in environmental and natural resource use policies in Australia and elsewhere. Some of these drivers may come "from above" (such as new government policies to reduce carbon pollution), or "below" (such as grassroots political action on a locally contaminated site). Stakeholders may acknowledge existing legislation and policy but they will not likely agree with all of it - and will often lobby for it to be amended. Getting public and stakeholder involvement in aquatic natural resource management issues is difficult, but not more so than other types of environmental or natural resource use management (which is often complicated by issues of private ownership). Governments must understand what the public, on whose behalf they are acting, want from their living aquatic resources so they can create appropriate policies, legislative instruments and implementation plans to achieve these goals. But there must then be a dialog with experts in performance assessment, whether they be biologists, economists or social scientists,

about what are the most cost effective and credible ways to measure progress towards implementing those plans.

The challenge for monitoring, assessment and management of recreational fisheries is not just to ask: "What is the recreational catch?", but also "What does the public want from their living aquatic resources; how best can government meet those aspirations; and how do we measure our progress towards achieving any subsequent plans put in place?". This second question is far more complex and will likely require all players to re-think their established attitudes – and this may well be the most difficult part of the challenge ahead.

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SESSION ONE - REVIEW OF RECREATIONAL FISHERIES RESEARCH AND MANAGEMENT

Overview

The introductory session provided an overview of the research and management of recreational fisheries in Australia, New Zealand and the United States. Presenters summarised recent progress in surveys in their jurisdiction and what they saw as the key issues facing the assessment of recreational fisheries. Both offsite and onsite surveys methods are being applied and all jurisdictions are better focussing their recreational assessments. For example, fisheries with quantitative stock assessments or explicit resource sharing goals were developing and implementing methods to estimate the total recreational catch. Many states were developing Research Angler Programs, where select groups of anglers were trained to collect quality data on catch rates and sizes of fish that were being caught.

The questions ranged from queries about management planning, processes to improve independent review of research and management, strategies to improve consultation and representation of stakeholders, issues on the valuation of recreational fisheries, animal welfare, and stock versus jurisdiction-based management.

Assessing Recreational Fisheries - Current and Future Challenges

Bob Kearney

The goals of this workshop are to obtain input from the many sectors with an interest in recreational fisheries throughout Australia and elsewhere as a step towards developing the partnership between recreational fisheries research and management and how we might approach the vision we would like for recreational fisheries in 20 years. These are laudable goals. But in my discussions with the conveners I did detect more hope than confidence that agreement on strategic change is likely to be an outcome. This is not surprising as it is, unfortunately, increasingly difficult for public servants to initiate long-term strategic change when the short term, politically expedient normally dominates the actions of governments. To achieve the 20 year vision will be difficult, but not impossible. In my opinion the chances of success will be greatly influenced by having agreed strategic approaches to the vision. These strategic approaches must be based on the best possible research across all relevant disciplines, including the obvious biological and social dimensions, and open, honest and thorough debate (true consultation) amongst all stakeholders.

In looking at a selection of the abstracts I detected considerable similarity and even familiarity in the representations from various state or Commonwealth agencies and a predictable commonality in industry sectors or lobby groups calling for more recognition and rights for anglers, particularly the ones they represent. I was not overwhelmed by presentations on more strategic issues.

As expectations of anglers are central to what an agreed vision might be, it is worth noting some of the objectives identified in the abstracts of angler representatives. They include:

1. greater recognition of the rights of anglers;
2. properly quantified and evolving economic valuation of recreational fishing;
3. a greater share of the total resource for anglers by measures such as more buy-out of commercial fishers and more recreational only species;
4. management based on sound science and more involvement of anglers in research;
5. more involvement of anglers' representatives in the management process.

All of the questions relating to rights and resource allocation to anglers are underpinned to at least some degree by the complex question of what is the value of recreational fishing. Why do anglers deserve more rights? I have on numerous occasions raised my concern that the answer that is given by anglers to this question is often unduly influenced by economic assessments based on expenditure. Expenditure is not regarded by many natural resource economists as a compelling indicator of value. It is often argued that economic efficiency should be the objective. Also, if we inappropriately emphasise expenditure we are inevitably going to move towards rights for the biggest spenders, or even the highest bidder. The likely consequences will include priority being given to those who spend the most. Will this mean that tourists, who fly in, use helicopters and stay in expensive hotels or lodges, get priority over locals? Think of the consequences for trout fishers in New Zealand. Or will priority be given to those with the biggest boats that consume most fuel, or to developers or owners of multi-million dollar waterfront properties who seek exclusion? It is truly imperative to look at the big picture and adopt the correct evaluation of why recreational fishing is of value.

What do the seafood consuming public, fish marketers and chefs think about allocation to recreational fishers? If anglers are to get a greater share of the resource, and not the same share of a greater resource, in a country that imports an increasing 70+% of its seafood, and where even government authorities are telling the public to eat more fish for health reasons, and preferably local fresh fish, then what ongoing compensation is going to be given to those who do not catch their own fish? And who will pay for this compensation? If anglers represent 20% of the population, and we are to have recreational only species and areas, why should we not have five times as many commercial only species and areas for those who catch the fish for the 95% of the population who buy seafood? Perhaps an alternative would be to only have four times as many species and areas for fish consumers, if anglers are not allowed to buy fish! Plus of course appropriate areas for those who do not catch or eat seafood and would like it left in the ocean. It is truly imperative to have the correct evaluation of why recreational fishing is important and should be respected as such.

Accepting that anglers time is as valuable as anybody else's, and financial resources are limited, is it really appropriate or cost effective to have anglers involved in all aspects of fisheries research? Here the differentiation between research for resource conservation and resource allocation is critical. For resource assessments that relate primarily to conservation issues in commercial fisheries management the global trend is clearly to put more weight on industry independent data. As anglers are a far more diverse group with arguably a much greater range of skills and equipment, and hook and line CPUE, even for the same individual fishers, is notoriously a very poor indicator of even relative abundance, it is easy to argue we should be looking for less angler involvement in data

collection for resource assessment purposes. However this debate is resolved I believe we will still need to stress the value of anglers as detectors of problems and even in identifying the causes.

I would suggest we need less angler or commercial fisher involvement in the science of the resource assessment process. This process should be based on the best possible data, which may in some cases be angler data, and analyses which are thoroughly independently reviewed before they impact the policy and management interfaces. This independence must be not only from the influence of industry, both recreational and commercial, but also from the government management and conservation agencies and various lobby groups, including NGOs, that influence them.

Angler involvement in research for resource conservation would appear to me to be most valuable for advising on if and when research is necessary and ensuring that research is independently carried out and peer reviewed, before the policy implications are developed. Anglers should then be involved in true consultation on what management should arise from completed research and how the appropriate management is implemented, including what measures are the most appropriate for resource conservation, and as I will argue in a minute, also for its allocation. Far too often 'consultation' on resource conservation amounts to a series of disjointed meetings of government representatives with disparate individual groups of stakeholders who are later collectively advised of what non-negotiable action has been taken. I believe it is the lack of true consultation on management which has supposedly been based on research that has led anglers to push for more involvement in research. Truly independent quality review of the science and its implications is the honest and cost-effective first step in a strategic solution. Genuine consultation on the independently reviewed assessments and open and effective mediation and review are the essential ingredients for addressing the social dimensions of resource conservation.

Obviously anglers and commercial fishers must be involved in the assessment of the social and economic issues that impact resource allocation, such as the valuation of recreational and commercial fishing and why anglers and commercial fishers should be given an allocation of what has been determined, independently, to be the sustainable harvest. I would argue that accurate assessment of the magnitude and composition of recreational catch is vital for resource allocation, but of only indicative value for resource assessments for conservation purposes. Again I would argue that truly independent, high quality review of all assessments by professionals in the appropriate fields, rather than by zealots or lobbyists, is the critical ingredient for both resource assessment and allocation. While high quality review may be relatively expensive I believe it represents the cost-effective long-term solution.

I cannot leave the resource allocation issue without my usual call for anglers to look more critically at allocation within the recreational sector and to be better prepared for the challenges to the total allocation to the recreational sector that will inevitably come from animal rights activists. Both of these are truly strategic issues. Allocation within the sector could be addressed by more restrictive total bag limits, such as a limit on the weight of the aggregate catch regardless of its species composition. Challenges on the basis of animal ethics will be to a number of angling practices. Catch and release, and in particular catch and release only fisheries, will be seriously challenged. I remain convinced that solutions closer to what anglers want will require much closer affiliations with the

seafood industry than anglers currently foster. I also believe that for such affiliations to be effective they will require considerable change to the methods most angling representatives would like to use to value recreational fishing.

An overview of monitoring and assessment of recreational fishing in Victoria

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Victoria's recreational fisheries are diverse and geographically extensive. Recreational fishing in Victoria occurs in both freshwater environments (inland lakes, river systems and water storages) and saltwater environments (predominantly within bays, inlets and estuaries or near-shore coastal waters). The main freshwater species targeted are redfin (*Perca fluviatilis*), trout and salmon, golden perch (*Macquaria ambigua*) and freshwater crayfish. The three main marine species of interest are black bream (*Acanthopagrus butcheri*), King George whiting (*Sillaginodes punctata*) and snapper (*Pagrus auratus*). Other marine species of interest to recreational anglers include Australian salmon (*Arripis trutta*), calamari (*Sepioteuthis australis*), garfish (Family Hemiramphidae) and flathead (Family Platycephalidae).

Monitoring is management driven to allow comprehensive assessment of levels of recreational fishing pressure and the impacts of alternative management measures. For the larger/more valuable Victorian marine/estuarine recreational fisheries (Gippsland Lakes, Port Phillip Bay, Western Port) the focus is on: (a) ongoing access point creel and attitudinal surveys to provide time series information on fishery profile and trends (including targeted catch rates for key species); (b) ongoing fishery-independent (including research angler diaries) monitoring of pre-recruit year class strength and recruitment patterns for key target fish stocks (black bream, King George whiting and snapper) as the main indicator of stock status; and (c) monitoring of discard rates and research on survival of discards for key target species.

Focus for smaller inlet/estuary recreational fisheries is on: (a) periodic access point creel and attitudinal surveys (where the fishery is large enough to warrant such expenditure) to provide time series information on fishery profile and trends; and (b) ongoing research and general angler diary programs to provide time series of information on catch rates, population age/length profile and pre-recruit year class strength for key target species in particular waters.

Victoria has developed methods to conduct cost-effective targeted telephone diary surveys to estimate total recreational catch and effort for specific recreational fisheries/stocks (namely the Port Phillip Bay/western Victorian snapper stock). However, this methodology will only be utilised if there is a clearly identified need for total recreational catch estimates of particular species for stock assessment models, or to assist establishing and monitoring compliance with specific resource sharing/allocation targets for particular fisheries/stocks.

Recreational fisheries management and research in Tasmania

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Tasmania's marine recreational fisheries are regulated using a range of strategies, including area and seasonal closures, gear restrictions and size and possession limits. Licensing applies to specific fisheries and gear types, for instance the taking of rock lobster, abalone, scallops, and net usage. Recreational catch share is explicitly recognized in the rock lobster fishery in the form a total allowable recreational catch (TARC) that is set annually.

The University of Tasmania is the main research agency undertaking marine recreational fisheries research in the state. Research focus is on three areas, estimation of catch and effort, socio-economic assessment, and biological studies on species of recreational significance. Catch and effort surveys include the 2007/08 statewide recreational fishing survey and biennial rock lobster and abalone surveys and are primarily based on a phone-diary methodology. Principal objectives include estimation of catch and effort at statewide and regional scales, information that is provided for resource assessment and in support of fisheries management. Additional surveys, combining on-site and off-site methods, include on-going monitoring of the inshore scallop fishery (phone and dive survey methods) and assessment of southern bluefin tuna catches (creel and logbook methods). A research angler program has recently been established to gather catch and effort trend data. Current socio-economic studies include surveys of the gamefish and charter boat fisheries and a regional socio-economic assessment, this work is being undertaken by post-graduate students. Greater emphasis on economic assessments is anticipated in the future with the commencement of a major FRDC initiative to develop research capacity in resource economics. Biological studies relevant to recreational fisheries include description of life history traits, post-release survival, and movement dynamics of key species.

South Australian recreational fisheries – participation, management and assessment

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Recreational fishing provides an important recreational or sport activity to more than 24 % of the South Australian population, annually (NRIFS 2000-01). Of these, almost 70% are males, with higher than average participation rates by youngsters (5 – 14 yrs of age) and "Generation X"(30 – 44 yrs of age) men. Rod and line fishing is the most popular fishing gear (84% of total fishing effort), with rock lobster potting and crab netting a distant second (11%). With SA's extensive coastline, line fishing mainly takes place from surf beaches, the numerous jetties/wharves found throughout the SA gulfs and west coasts embayments, as well as from the banks of the River Murray. Southern calamary, blue crabs, Australian herring and salmon are key species taken by shore fishers. Almost 38% of the total effort is undertaken by boat fishers, with KG whiting, snapper, garfish, calamary, blue crabs and

rock lobster mainly harvested by this sector. In 2000/01, SA recreational fishers were either "local" (< 40 km) or distant travellers to their fishing locations but with only relatively low levels of effort by interstate participants in most areas of the state. With the City of Adelaide dominating the population size of the State (73 % of 1.5 million residents), highest levels of effort are exerted in waters adjacent to Gulf St. Vincent (35%), with effort generally decreasing with greater distances from Adelaide. More than 15 % of the total effort occurred in SA's inland waters, and this was predominantly in the River Murray.

The SA Recreational Fishery is managed through input (gear restrictions) or output controls (bag, boat and size limits and seasonal closures for key species- eg snapper, Murray Cod, and rock lobster). No general recreational licence has been implemented in this state, although annual permits apply for rock lobster pots and a limited number of recreational nets. A licence-managed recreational charter boat fishery has now been in place since September, 2005, with snapper and King George whiting being the most commonly harvested species.

Under the new SA Fisheries Management Act, 2007, there are now requirements to monitor biological, economic and social performance indicators for all SA Fisheries, including recreational fishing. To fulfil the first component, statistically robust and regular estimates of annual recreational harvest and effort are required, and during 2007/08, a state-wide recreational fishing survey on the key managed species is being undertaken. The survey follows the same methodology as that used in the NRIFS 2000-01, combining an initial phone-based screening survey of 7500 randomly chosen SA households (September, 2007) with a 12 month phone/diary survey of 1311 recreational fishing households (Oct, 2007 – Sep, 2008). These components of the survey will estimate participation rates by SA fishers and the harvested numbers of marine and freshwater fish. At the same time, spatially and temporally stratified day-time on-site interview surveys are being undertaken by trained interviewers at key boat ramps/jetties and beach fishing sites, to collect representative data on size compositions of the key species for later estimation of harvest weights. The data from these latter surveys are supplemented with those collected by over 100 avid anglers fishing in marine and inland waters through a recreational fishing log book provided by PIRSA Fisheries. Future research on the social factors driving recreational fishing in SA will assist in future monitoring of the social performance indicators for this sector.

Western Australian recreational fisheries

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The Recreational Fishery

Each year 565,000 Western Australians participate in fishing recreationally. In Western Australia recreational fishers only need a licence to fish for rock lobster, abalone and marron and to participate in freshwater angling and netting. As at mid 2008 there were over 58,000 recreational licences on issue. There is no licence required for marine angling, which makes up a majority of recreational effort.

Research Priorities

The major research priorities are surveys of catch and effort in key recreational fisheries including west coast and Gascoyne scalefish, abalone, rock lobster, marron, freshwater finfish and aquatic tour operator (charter) fisheries. The lack of a system to easily identify recreational anglers also makes it logistically difficult to estimate total effort and catch. Ongoing collection of age samples of key recreational species are used as inputs to determine the stock status of these species.

Innovative Developments in Research and Management

The development of a regional approach to research and management is assisting with the implementation of Integrated Fisheries Management (IFM) and addresses the issue of how fish resources can be best shared between competing recreational and commercial fishers within the broad context of Ecologically Sustainable Development.

The challenge of the large coastline and rapid northern regional development will both change the distribution and increase the total effort and catches of recreational fishers, particularly in this region of the state. Monitoring strategies for the collection of ongoing research information from recreational fisheries are under investigation with a number of survey techniques run simultaneously to compare cost effectiveness of each approach. The outcomes of comparison among techniques will allow the most efficient methods to be applied.

A summary of recreational fishing in the Northern Territory

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Recreational fishing activity in the Northern Territory (NT) is perhaps most easily explained if one considers the NT in terms of four main areas: i.e. the Victoria River district in the west, the Darwin district (i.e. within a 200 km radius of Darwin), Arnhem Land and the Roper-McArthur district in the east. The reason being, that these areas show marked differences in terms of population density, land ownership and the relative impact of fishing tourism.

Access to many fishing areas in the NT is limited, either permanently (in the case of Aboriginal land, e.g. Arnhem Land) and/or seasonally (due to flooded roads in the wet season). Recreational fishers also require (free) permits to access waters overlying Aboriginal land (as a result of the Blue Mud Bay High Court decision) but do not require fishing licences. Most fishing in the NT is done from boats due to large tidal variations (~7 m) and the presence of saltwater crocodiles.

Despite its size, the Victoria River district is relatively lightly fished, because the area is remote and sparsely populated and the river hazardous to navigate and slightly less productive than other systems in the NT. The Darwin district contains roughly 70% of the Territory's ~200,000 strong population and it is here that most recreational fishing effort (both inland and coastal) is concentrated. There are several large estuaries in the region (e.g. the Daly, Adelaide and Mary Rivers

as well as the East, South and West Alligator Rivers) and these are very popular with both locals and visitors in search of the prized barramundi (*Lates calcarifer*).

Rocky reefs can be found along most of the Territory's coast but their extent and the fish species they support do vary. The primary target species include the black jewfish (*Protonibea diacanthus*) and the golden snapper (*Lutjanus johnii*), but a range of other snappers, emperors and cods are also caught. Pelagic species such as mackerel, trevally, tuna and queenfish are common, particular in the dry season. Interest in the pursuit of billfish (e.g. sailfish and marlin) has increased substantially in the last few years.

Relatively little recreational fishing occurs within Arnhem Land, and it is mostly concentrated around a number of remote coastal fishing camps/resorts as well as the mining towns of Nhulunbuy and Alyangula (on Groote Eylandt), both of which support active fishing clubs.

Fishing effort in the Roper-McArthur district is dominated by dry season visiting fishers, most of whom are from interstate, predominantly Queensland and New South Wales. Several permanent or semi permanent camps have been established at a number of sites in the district, most notably on the Roper, Limmen Bight, McArthur, Wearyan and Robinson Rivers.

Research and management of recreational fishing in the NT is undertaken by the Fisheries Group of the Department of Regional Development, Primary Industry, Fisheries and Resources, whilst enforcement is the responsibility of the Marine and Fisheries Enforcement Unit of the NT Police.

Catch controls include size limits (for barramundi, cods, gropers and mud crabs) and a General Personal Possession Limit (GPPL) of 30 fish or equivalent (with some exemptions). The GPPL includes no more than 5 each of barramundi, black jewfish, Spanish mackerel and golden snapper. Ten tropical rock lobsters (*Panulirus* sp.), 10 mud crabs (*Scylla* sp.) and 10 L of molluscs (in their shell) can be retained in addition to the GPPL. Boat limits (i.e. 30 if ≥ 3 people on board) apply for both lobsters and mud crabs. Seasonal area closures apply to the lower Mary and Daly Rivers during barramundi spawning periods.

Information on recreational fishing catch, harvest and effort patterns in the NT is primarily derived from recreational fishing surveys such as those undertaken in 1986, 1995 and 2000/2001. Another (12 month) recreational fishing survey is scheduled to commence in April 2009. Some of the challenges facing recreational fisheries management in the NT include: population growth, increased boat ownership, spatial expansion in conjunction with remoteness, technological improvements that increase fishing efficiency (e.g. GPS and depth sounders) and greater information sharing (email/internet fishing forums) as to the best times, tides and techniques.

An overview of recreational fisheries-related monitoring and research being carried out by Queensland Department of Primary Industries and Fisheries

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The Department of Primary Industries and Fisheries (DPI&F) manages the harvest of Queensland's fish, mollusc and crustacean species and the habitats in which they live. To achieve this aim, the DPI&F ensures that information is collected routinely and on an as-needed basis. A large proportion of this information is collected by the DPI&F using a range of core- and externally funded, routine and responsive, long- and short-term, monitoring and research projects.

Fisheries for most Queensland species cannot be regarded as "recreational" per se (the exception being those for some freshwater species). Rather, recreational fisheries are usually components of multi-sector, multi-species fisheries. Therefore, most recreational fisheries-related monitoring and research programs carried out by the DPI&F are actually components of bigger programs to understand, assess and manage the State's harvested fish species.

One way of categorising the monitoring and research of Queensland's recreational fisheries carried out by the DPI&F is the following:

- Some projects collect data directly from stakeholders within existing recreational fisheries (i.e. fishery-dependent sampling)
- Some projects study recreationally caught species, but are carried out by DPI&F staff independently of existing fisheries
- Some projects study recreationally caught species independently of existing fisheries, but benefit from the voluntary assistance of recreational fishers.

Fishery-dependent sampling activities carried out by the DPI&F obviously rely on the voluntary assistance of recreational fishers, and the extent of these activities has expanded greatly during the last decade. In short, there are a number of routine, voluntary data- and sample-collection programs in which recreational fishers can get involved, namely filling out diaries, donating fish samples (e.g. frames), answering questions about their fishing activities at boat ramps and allowing their fish to be measured by scientific staff at boat ramps, competitions or shore based fishing locations. The data and samples collected by these sampling activities are used to obtain important information about the extent and value of recreational fisheries, as well as estimate biological characteristics (e.g. length and age) of many of the species being caught recreationally. It is worth noting that DPI&F sometimes engages community groups (e.g. CapReef) or universities (e.g. JCU) to carry out fishery-dependent sampling.

Some recreationally caught species, such as mud and sand crabs, coral trout and red throat emperor, are currently being monitored using routine (annual) fishery-independent surveys. The data collected in these surveys are used to estimate indices of abundance or population characteristics. Other

fishery-independent research projects being carried out by DPI&F include an FRDC-funded project to collect information on a number of rocky reef finfish species, particularly pearl perch, cobia and teraglin and an MDBC-funded project to improve survival of stocked fish (e.g. silver perch and Murray cod) through modifying their predator avoidance behaviour.

Recent examples of recreational fishers voluntarily assisting with fishery-independent surveys conducted by DPI&F have included a number of projects relying on tagging fish en masse to validate estimates of age (e.g. tailor) or examining survival rates of discarded line-caught fish (red emperor, crimson snapper and saddletail snapper).

Management and assessment of the recreational fisheries in New South Wales: an overview

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The National Recreational and Indigenous Fishing Survey (NRIFS 2000-01) estimated that approximately one million anglers went fishing in NSW at the time of the survey (17% participation rate), which was approximately 30% of all recreational fishers in Australia. It is estimated that the numbers of anglers are increasing by about 4% per year. The NRIFS estimated that these fishers caught approximately 14.5 million finfish and 18 million crustaceans and molluscs. The recreational fisheries in NSW are diverse and complex; taking place in coastal, estuarine and freshwaters and being both shore- and boat-based, targeting a multitude of species using various types of fishing gears. Some fisheries are relatively specialised, targeting specific species, whereas others are more general.

As in other states and territories, the recreational fisheries in NSW are managed by fishing gear restrictions, minimum and maximum size limits, possession limits and spatial and temporal closures. The charter boat fishery is managed with additional provisions within the NSW *Fisheries Management Act* (1994).

In 2001 the NSW Government introduced a General Recreational Fishing Licence – the current fee ranges from $6 for 3 days to $75 for 3 years. All monies raised by the NSW Recreational Fishing Fee are placed into the Recreational Fishing Trusts and spent on enhancing recreational fishing in NSW. Revenue from the licence enabled the creation of 30 estuarine Recreational Fishing Havens, where commercial fishing was removed from 24% of the state's estuarine waters, including several major lakes and rivers, and these areas were legislated as recreational fishing only (ROFA's) – a major shift in the allocation of the fisheries resource in NSW. Fees from the Trusts have also been spent on improving angling facilities, communications and education, compliance, management, the Fishcare volunteer program, artificial reefs, fish aggregating devices, restocking, habitat restoration, survival of released fish, biology of key species, tournament monitoring and specific economic and fishery surveys.

Recent assessments of catch and effort of recreational anglers in NSW have targeted a specific fishery using on-site surveys in specific locations for specific reasons. For example, surveys of recreational fishing were done in Lake Macquarie and Tuross River before and after the introduction of the Recreational Fishing Havens. The current survey of recreational fishing in estuarine and coastal waters in the Sydney Bioregion is being done to quantify the temporal and spatial distribution of angler catch and effort in this highly populated area. No state-wide survey of recreational fishing has been attempted since the NRIFS – despite plans to do so.

Recreational fishers are the major harvesters of several key species in NSW; there is no commercial fishing permitted in inland waters and best estimates indicate that more than 70% of the total harvests of popular estuarine and coastal species such as bream, mulloway, dusky and blue spotted flathead are taken by recreational anglers. There is a clear need to incorporate recreational harvests into resource assessments of such species. There is a further need to understand changes in recreational fishing trends and their consequent impacts on the fisheries resources. Greater knowledge of social and economic factors associated with recreational fishing may assist with achieving this and would help in developing future plans for managing the State's living aquatic resources.

The marine recreational fisheries statistical survey in the US: challenges and changes

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There are more than 14 million marine recreational anglers in the US, fishing from shore, private boats, charter boats (small groups that hire an entire boat), and party boats (up to 100 anglers paying per head). Collectively, these anglers catch over 450 million fish annually. Recreational fishing can have a huge impact on marine species, and for some species, the catch by recreational anglers surpasses the catch by commercial fishermen. However, recreational catch and effort is more difficult to assess than commercial catch and effort. In 1979, the US National Marine Fisheries Service (NMFS) instituted the Marine Recreational Fisheries Statistical Survey (MRFSS) to assess catch and effort in the recreational fisheries. This survey includes two components: a telephone survey of coastal households to estimate fishing effort, and a dockside interview to estimate catch rate and species composition. Between 2004 and 2006, MRFSS was reviewed by a national panel of renowned fisheries scientists, statisticians, and economists. Recommendations by the panel were to completely redesign MRFSS, including creating a saltwater angler registry, requiring logbooks from the recreational-for-hire sector (charter boats and party boats), redesigning the sampling frames for onsite and offsite sampling, testing assumptions such as differences in nighttime and daytime fishing, standardizing methods between different states and regions, and increasing funding and personnel. These changes will take several years to implement but should eventually provide the timely, precise, and accurate assessments of recreational catch and effort necessary to meet emerging management needs.

Overview of recreational fisheries policy, management and research in New Zealand

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New Zealand supports some of the best recreational fishing in the world and some estimates of the catch are of the order of 25 000 t annually. Management of this valuable resource requires a wide variety of information. In response, New Zealand has developed a suite of research approaches that provide basic, broad-scale estimates of the catch of all species right through to the detailed and precise information needed for stock assessments of species where recreational catch is a substantial proportion of total extractions. Direct observation has emerged as the approach of choice for stock assessment needs and in situations where fishing is concentrated and readily observed. However, funding constraints mean that less direct methods are necessary for situations where fisheries are broadly spread, very small, or more or less cryptic, especially given the large number of target species and methods employed by New Zealand fishers.

A major use of research information is in support of the Shared Fisheries Project, designed to improve the management of fisheries where customary, amateur and commercial uses intersect. This project's aim is to increase the value obtained from the use of shared fisheries, encompassing both market and non-market values. Two key objectives are to increase certainty in the allocation framework and to better recognise non-commercial values. New Zealand's Ministry of Fisheries has consulted on some possible ways forward but the response was mixed. A tri-partite working group of customary, amateur and commercial interests has been established since, but the overall project's progress is less clear.

Information – the biggest issue for the recreational fishing sector

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Recreational fishing in Australia faces several challenges in the next decade. Perhaps the biggest challenge lies in access to and availability of information. As recreational fishers take a more active role in natural resource management, there is an impression that we do not have access to the same data as management agencies.

National and state recreational catch statistics are often out of date and commercial catch figures can be hard to find. Information on the social and economic characteristics of recreational fishers is limited and an appropriate estimate of the value of recreational fishing to society is non-existent.

The true value of reliable data for this sector needs to be realised by all stakeholders including government.

Until such time as appropriate, long term investment in recreational fishing data is made at a national and state/territory level, management of the sector will be ad hoc and unable to deliver on strategic goals for the sector.

Recfish Australia in partnership with the Fisheries Research and Development Corporation has a major research, development and extension initiative in the form of Recfishing Research. While Recfishing Research is able to identify priorities for research and investment and knowledge gaps, it is not able to fund the research and ongoing monitoring that is required for this sector.

The development of an effective investment model for the collection, storage and dissemination of recreational fishing information is a major challenge but one that will pay huge dividends in the form of a sustainably managed recreational fishery for future generations.

SESSION TWO - AQUATIC RESOURCE MANAGEMENT AND RECREATIONAL FISHERIES RESEARCH

Overview

This session was a policy oriented-discussion about the partnership between the managers, researchers and anglers. The organising committee recognised there was a need to discuss the policy questions on "why" recreational fisheries needed to be assessed, not just discuss the details of "how" to do the assessments. There was also a need to recognise the contributions that social science and environmental economics would likely make to this debate. As the ASFB is predominately represented by biological and fishery scientists, this was likely to be an important future issue for the Society. The need for outcome-based research (i.e. research where the outcomes were clearly defined and would be used by management) was also emphasised.

A key issue that was raised was the role of anglers in research and management. There was recognition that the science for, and management of, recreational fisheries needed new types of thinking. The models that had developed for commercial fisheries would not be easily transferable to recreational fisheries. There was, in particular, a need to understand the behaviours and motivations of recreational fishers so as to understand the likely response of anglers to either research (such as surveys) or management (such as changes to regulations).

Finally, some of the presenters indicated that rights and allocation issues are central to the debate. Statutory property rights are one of the most important management strategies for commercial fisheries in Australia and overseas. Additional deliberation was required on how these approaches could be extended to the recreational sector. If such rights were granted, then what are the responsibilities of anglers, particularly with respect to the provision of information for assessments?

Development of a plan to address national needs for recreational fishing data for fisheries management and development

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Governments and industry have recognised the importance and potential for further development of the recreational fishing sector. To increase and measure the social and economic values of the sector, and to ensure sustainability of the fisheries, there is a need to effectively and efficiently collect, curate and share appropriate recreational fisheries data. A systematic national approach to the collection and management of recreational fisheries data would also assist with the management of the sector and prediction of the impacts of regulatory decisions and program implementation.

The approach proposed here recognises that the NRIFS provided information that, while useful and widely used, did not address many sector and government needs. Each jurisdiction continues to

independently collect recreational fisheries data for stock assessment, resource allocation and other management requirements.

Late in 2006, all jurisdictions and the sector agreed on the need for a coordinated national approach to collection of recreational fisheries data. The Australian Fisheries Management Forum, through its Sub-committee for Science and Research has been liaising with Recfish Australia and Recfishing Research (FRDC 2007/227) concerning a national approach to data collection and management.

The project aims to develop a national plan for the efficient and effective collection and management of recreational fisheries data for Government and industry. The project will develop agreed outcomes for the sector, and then summarise the information requirements to support these fishery, biological, social and economic outcomes.

The resulting plan will assist R&D investors and providers to focus their resources on areas of national need and priority. It will assist researchers to identify and access recreational fisheries data sets, thus expanding the resources engaged in analysis and methods development. It will also assist with access to information for development and extension purposes.

Overall the effective and efficient collection and management of social, economic and biological data will facilitate increased understanding of the social and economic values and impacts of the fisheries, enhanced management of the fisheries, and the further development of the sector.

The widespread recognition and uptake of this national plan will facilitate constructive networks, industry-government partnerships and dialogues. In this way the plan will be the starting point for a continuing process of improving the objective basis for managing and developing Australia's recreational fisheries.

The project working group will prepare a report which will recommend how current and future recreational fisheries data sets can be made more accessible to stakeholders. It will make specific reference to the collaborative involvement of industry-based data collection programs in fisheries research, monitoring, assessment and management programs.

Understanding the recreational fishing sector

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Dedicated recreational fisheries management has a relatively recent history in Australia. Information gathering to better manage the recreational fisheries is also recent and is based upon a number of fundamental assumptions that should be reviewed.

One major assumption is that Catch Per Unit Effort (CPUE) measured in number of fish per hour is a useful measure. It is argued that this measure must be changed to number of fish caught per day, which is a management unit less subject to error with the skewed distribution of recreational catches.

Sampling methods need to recognise the highly skewed nature of recreational catches and be designed to provide defensible, reliable information. Socio-economic studies should include inefficient anglers, but studies designed to improve the biological management of recreational fisheries should try to concentrate on measuring the catches of the most effective (not necessarily the most efficient) anglers. Extrapolations resulting from data sets needs to be carefully assessed with all studies.

Other basic biological assumptions such as constant recruitment and constant fishing mortality need to be urgently reviewed if recreational fisheries are to be sustainable.

It is argued that additional research into recruitment drivers which can vary far greater than mortality rates should be the major focus of new studies and this will allow pro-active management. Recreational fishers are becoming increasingly concerned about results that tell them what should have been done five years ago.

Finally, it is recommended that research should more closely examine behavioural responses to management in an effort to determine future consequences of displaced or dynamic fishing as a result of management intervention. This requires new skills in socio-economic research to manage the human response of a large and diverse group.

In this way Australia can manage recreational fisheries to cater for a quality experience without undue impact on the fish stocks upon which their catch expectations rely.

Managing many with little: herding chooks in the Great Barrier Reef Marine Park

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The waters of the Great Barrier Reef Marine Park are a magnet for recreational fishing. Recreational fishing is the most popular extractive use of the Marine Park and fishing as a pastime is deeply engrained in the social and economic fabric of coastal Queensland.

Best estimates are that retained annual catch by recreational fishing is of similar magnitude to the retained commercial catch. Information available to managers about the recreational part of the catch is limited but the cumulative effects of recreational fishing together with commercial fishing, climate change and declining water quality, particularly around growing population centres, presents future challenges for managers of the Great Barrier Reef Marine Park.

A spectrum of management approaches is outlined, including regulation, spatial zoning as well as recent thoughts about driving behavioural change and environmental stewardship through education and eco-accreditation. Approaches are discussed with respect to their information and compliance needs as well as the measurability of their effectiveness.

Strengths and weaknesses of recreational fisheries management and research strategies: a recreational sector perspective

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Recreational fisheries took their place alongside commercial fisheries on the national fisheries policy, management and research agendas during the 1990s. Estimates of the increasing take of many inshore species by the recreational sector coincided with their demands for increased resource shares. The rising prominence and recognition of state and national representative bodies and the release of the 1994 National Recreational Fisheries Policy reflected increased national recognition of the sector in terms of resource use and the social and economic benefits that recreational fishing represents. By the end of the decade, each state had a dedicated recreational fisheries program and manager with close links with their respective "constituents".

The National Recreational and Indigenous Fishing Survey (NRIFS 2000-01) was the culmination of unprecedented planning, collaboration and investment by fisheries jurisdictions nationally. While it was a landmark achievement, subsequent discussions among governments and the recreational fishing sector indicated that the disparate information needs for fisheries management and sector development require a range of targeted and cost-efficient approaches.

The strengths of the current management and research strategies as they apply to recreational fisheries are based on a number of factors. The strong ethos of shared responsibility and stewardship built up between governments and recreational fishers is now reflected in many co-management and collaborative research arrangements. This ethos can be seen running through Research Angler Programs, angler-based tagging programs, phone-diary surveys and community-based monitoring and survey projects. While further development is needed, the massive potential capacity for volunteer contributions to research is clear. The role of Recfishing Research in coordinating national investment, angler participation and extension of the results of research and development under the Released Fish Survival (RFS) program (www.info-fish.net/releasefish/) exemplifies the contribution that the sector can make to more sustainable and ethical fishing practices. The NRIFS 2000-01 and RFS programs typify another strength – the increased tendency for governments and the sector to take a national approach to recreational fisheries issues that, previously, were mainly seen as the province of state jurisdictions working independently of each other. The project *Development of a plan to address national needs for recreational fishing data for fisheries management and development* is an excellent current example.

The use of fisheries management planning processes to develop R&D needs and funded programs, linked to clear management objectives and performance measures is now commonplace. As well as improving the linkages between recreational fisheries management and research, these processes feature recreational fisher and wider community involvement. These more strategic, inclusive and accountable processes are being driven by state fisheries and, in some cases environmental and planning legislation, as well as the strict requirements mandated under the Commonwealth *EPBC Act*

1999 for fisheries with export components. Longstanding practices involving anglers in planning, implementing and assessing inland fishery stocking regimes continue, with careful attention to improving angling outcomes, stocking efficiency and environmental and biodiversity impacts.

Progress in these areas of shared stewardship and management strategies has been accompanied by increased and more strategically focused investment in recreational fisheries research, monitoring and assessment. Research in the "core business" areas of fisheries agencies – fishery sustainability – has been strengthened in the recreational fisheries area by continual improvements in methods development (e.g. creel to bus-route to phone-diary survey). While there have been some improvements in research - and its application - in the assessment of social and economic benefits of recreational fishing, realising the full potential of these fields is still some way off.

It is impossible to overstate the role of the Fisheries Research and Development Corporation (FRDC), in helping to lead a coordinated national approach to recreational fisheries research and development. Over the past decade, FRDC has invested increasingly in recreational fisheries research and development based on a sound strategic analysis – integrated across all areas of fish resource use - of the environmental, social and economic challenges facing fisheries in Australia. Together with recreational fishers' national peak body, Recfish Australia, FRDC has established Recfishing Research (www.recfishingresearch.org) to help prioritise its investment in recreational fisheries, coordinate this investment and maximise resulting benefits.

Viewed from a national perspective, many weaknesses in current management and research strategies stem from the disparities between jurisdictions in such matters as geography (eg size, climate), population (eg size, density, distribution) and resourcing. The resulting differences in needs, priorities, policies (eg licensing) and opportunities to address more than the core responsibilities in managing recreational fisheries – coupled with the states' jurisdiction over virtually all recreational fisheries – have impeded national progress. This can be seen in areas such as the unresolved needs for national recreational fisheries statistics and for proactive approaches on looming issues, notably climate change and water management impacts on fishing and the likelihood that recreational catch demand will overshoot available resources.

The lack of consistent government appreciation of the value of recreational fishing to Australia's economy and the social benefits at individual, family and community levels disadvantages recreational fishing, resulting in dislocated ad hoc planning and investment at a national level. There is no meaningful equivalent of the Gross Value of Production which underpins the ongoing recognition of and investment in commercial fisheries nationally. The continuing paucity of research into the social and economic attributes of recreational fisheries is both a consequence and a contributory cause of this situation and highlights these priority areas of recreational fisheries R&D. This situation is not helped by the fact that, today, most states have abandoned sector-based organisational structures in favour of resource-focused structures. This has come at the expense of the recreational fisheries program leaders who provided dedicated conduits between management and research planning processes and the recreational sector.

While various forms of co-management are being used in areas such as management planning, catch limit reviews and fish stocking, many programs continue to miss the mark in terms of delivering

outcomes sought by recreational fishers. Without an understanding of fishers' aspirations, preferences and motivations, many programs continue to respond to fishers' demands expressed as inputs - more fish stocked, tighter regulations – instead of desired outcomes. This situation is hampered by "research and development strategies" that are encyclopaedic wish-lists and poor communication that can - for example - turn fishers' support for biodiversity conservation programs to heated opposition when the use of biocides to remove trout is necessary or when trout are labelled "alien".

Most representative bodies are generally satisfied with how agencies research programs address the needs of ensuring that fisheries continue to be sustainable. However, in some states, recreational fisher involvement in project development and priority setting needs improvement. As more recreational catch shares are assigned and more inshore scale-fisheries are re-allocated to the recreational sector, stock assessments and fishery performance measures will become increasingly dependent on reliable and cost-effective recreational fishery monitoring programs. Voluntary involvement by fishers and fisher-based programs will play important roles. This will only be possible with close collaboration between researchers and recreational fishers.

To a large extent, progress will depend on how well the recreational sector can communicate and build relationships with their constituents and with government and how positively they engage in traditional and emerging planning and management processes affecting recreational fisheries. This will require a clear well informed vision of where the sector sees recreational fishing in the future. That vision will inform research and development priorities for the sector and guide government and industry investment in key areas including building the sector's research and development capabilities. All of this will require far-sighted leadership.

SESSION THREE - RECREATIONAL FISHERIES RESEARCH METHODS

Overview

Aldo Steffe

The recreational sector is a large user-group that harvests considerable quantities of important fisheries resources throughout Australia. Thus, this sector is a significant source of fishing-related mortality for many popular finfish and invertebrate species. As such, there is an increasing need to estimate the amount of fishing pressure exerted by recreational fishers and to estimate the associated catches. Recreational fishing surveys are undertaken by fisheries agencies to collect the information needed to derive the estimates of effort and catch. These surveys may also provide information on other aspects of the recreational fishery and its management, such as, indicators of fishing quality (e.g. catch rates, size structure of fish populations), angler demographics (e.g. document where the anglers come from), angler attitudes and perceptions (e.g. angler opinions about a variety of management issues) and economic information (e.g. estimates of expenditure related to fishing).

Recreational fishing surveys can vary greatly in size and complexity depending on the spatial scale of the survey area (Pollock et al. 1994). This means that recreational fishing surveys can be very expensive and many have complex survey designs. Unfortunately, there are no simple "off the shelf" survey methods designed to fit all situations. Each fishery has its own unique characteristics which usually require a customised approach to sampling. A comprehensive review of angler survey methods can be found in Pollock et al. (1994). A brief overview of these methods follows.

There are two main groups of survey methods, known as, off-site and on-site methods (Pollock et al. 1994). Off-site survey methods are done by surveying recreational fishers away from the fishing sites and are usually based on sampling from a list of fishers (e.g. licence frame, list of telephone numbers, list of households). Off-site methods include mail surveys, telephone surveys, surveys done at the fisher's residence or in tackle shops, diaries and logbooks. In contrast, on-site survey methods are done by surveying recreational fishers at the fishing sites and are based on sampling from a spatio-temporal frame (i.e. a list of all possible fishing sites and times within the survey area). On-site methods include access point surveys (e.g. traditional access point surveys and bus route surveys) which interview fishers and enumerate fishing effort at the end of the fishing trips and roving surveys which interview fishers and enumerate fishers during their fishing trips. Instantaneous and progressive counts to quantify fishing effort are regarded as roving methods.

It is often useful to use a combination of off-site and on-site methods in a survey. These types of surveys are known as complemented survey designs (Pollock et al. 1994). The Marine Recreational Fisheries Statistical Survey (MRFSS) is an example of a complemented survey that was designed to provide effort and catch estimates for saltwater anglers in the United States of America. The MRFSS has a telephone (effort)-catch (access) complemented survey design (Committee on the Review of Recreational Fisheries Survey Methods 2006).

Recently, an extension of the access method has been developed to improve the accuracy and precision of fishing effort and harvest estimates derived from access point surveys (Steffe et al. 2008). This survey design is known as a supplemented design because it uses auxiliary data on fishing effort derived from automated traffic counters at boat ramps or counts of fishing trips from web cameras to supplement an access point design.

This session of the workshop is intended to focus on methodological issues associated with recreational fisheries research and to showcase cutting-edge approaches that are being used to tackle the difficult issue of estimating fishing effort and catch in recreational fisheries at a variety of spatial scales. We are fortunate that the four invited speakers will provide different perspectives on this problem. Sandra Diamond will give us a perspective from the United States of America, Jeremy Lyle will provide his insight into off-site surveys, Bruce Hartill will emphasise the importance of on-site surveys from a New Zealand point of view, and Karina Ryan will talk about the use of angler licence frames to survey anglers on a regional spatial scale in Victoria.

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New ideas and methods for assessing catch and effort in marine recreational fisheries

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In the US, over 14 million recreational anglers currently catch over 450 million fish annually, and these numbers are expected to increase in the future. Fisheries managers are increasingly concerned about the impact of recreational fishing on marine stocks, and have been seeking better ways to assess recreational fisheries. However, recreational catch and effort is more difficult to assess than commercial catch and effort for several reasons. First, there are many more recreational anglers than commercial fishermen, and they land their fish at more diverse locations, including private land or docks that are difficult to sample. In addition, recreational anglers can fish from shore, jetties and piers, private boats, guided boats, charter boats (small groups that hire an entire boat), and party

boats (up to 100 anglers paying per head), and each of these modes of fishing requires different sampling techniques. The difficulties in assessing effort and catch, particularly discarded catch, have resulted in significant criticisms and changes to the Marine Recreational Fisheries Statistical Survey conducted by the US National Marine Fisheries Service since 1979. However, with the advent of new ideas and technologies, improvements over the traditional recreational fisheries assessments may be possible. In this talk, I will review some new ideas for assessing recreational fisheries, including rights-based harvest tags like the ones used by hunters, and technology used in commercial fisheries, such as vessel monitoring systems and electronic logbooks. Some of these programs are currently in use in fisheries in the US, and may be adaptable to recreational fisheries in both the US and Australia.

Application of the telephone diary methodology in large scale recreational fishing surveys

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In evaluating design options for recreational fishing surveys, factors such as the scale of the survey (spatial and temporal), objectives (what information is required and how it will be used) and available budget need to be considered. For large-scale studies, on-site survey methods may be logistically difficult and too costly to implement and, as a consequence, such surveys often have some reliance on off-site survey techniques. The telephone-diary methodology is an off-site survey approach that has been developed to address a broad range of policy issues including resource sharing and allocation, resource assessment and sustainability, and economic impacts (expenditure and investment), and has been applied to a range of large-scale Australia studies, including general population and licensed fishing surveys.

Survey Methodology

The methodology involves a two stage design, an initial screening phase to gather profiling information from a sample of the population and a subsequent, intensive phase, in which respondents provide detailed catch and effort information over a period of time.

Screening interviews are conducted by telephone using a structured questionnaire, tailored to the requirements of the specific survey. The primary function of the screening interview is to collect profiling information as well as to establish eligibility to participate in the follow-up diary phase. The profiling information is important not only to characterize the sample population but also to examine issues relating to representation and response.

The telephone-diary survey differs from conventional angler diary surveys in two important ways; firstly the diary is employed more as a ‘memory jogger’ than a logbook and secondly, responsibility for data collection rests with survey interviewers and not diarists. Typically, diary survey response rates are low and data quality can suffer in terms of completeness, generality and consistency. Since the burden of maintaining the diary rests with the respondent, instructions may be misinterpreted and data may be incomplete or ambiguous. The need to periodically remind respondents to submit

documentation creates a further problem, whereby information that has not been diarised must be collected on the basis of recall, if at all. By contrast, the telephone-diary approach effectively transfers the burden of data collection from the respondent to the survey interviewer. Data collection is undertaken by brief telephone interviews in which trained interviewers recorded details of any fishing that has occurred since the last contact. Detailed information, such as species targets, fishing method, platform (boat or shore), water body type (river, lake, estuary, coastal, offshore, etc), and reasons for release, for each individual fishing event are collected and recorded during the telephone interview. This in turn, provides for greater data utility, for example fishing effort can be apportioned between target fisheries, methods, fishing platform, and so on. Furthermore, activities such as shore-based and night-time fishing are covered, activities that are often difficult to assess in on-site surveys.

Data Quality Issues

As in any survey seeking to provide unbiased population estimates, the selection of a representative sample of the population is critical. Sample representation or coverage can be addressed in part by calibration against known demographic and/or household characteristics (e.g. census data) but there are also potential errors associated with participation in the survey, namely issues related to non-response and data reporting quality.

Some level of non-response is inevitable in any survey and must be accounted for in any responsible analysis. Non-response can introduce biases since non-respondents often differ in their characteristics to respondents. Obviously, the higher the response rate, the lower the impact of non-response errors. Across a number of surveys using the telephone-diary method, screening survey response rates have been high (> 80%), with consistently high diary uptake and completion rates (> 90%). By comparison with traditional diary surveys these survey response rates are exceptional and represent an important performance indicator as to the efficacy of the methodology.

Nevertheless, biases arsing from non-response have been examined both through follow-up surveys and the use of profiling information. For instance, in the 2000-01 national survey we found significantly lower fishing participation rates amongst the non-response group, the net impact of adjusting for screening non-response was a reduction in the estimated national fishing participation rate from 21.3 to 19.5%. Furthermore, diary uptake and completion rates tend to be higher amongst the more avid fishers, who contribute disproportionally more to the overall catch and effort. These experiences highlight both the importance of minimising non-response in the first instance and the need for appropriate evaluation of its influences, issues that have too often been discounted or ignored in recreational fishing surveys.

The use of the diary in conjunction with regular contact with respondents also represents an important strategy to reduce recall bias effects. Ideally fishing details are recorded soon after the activity has been completed but, in any case, respondents are contacted routinely within a few weeks of activity such that details of any non-diarised fishing are obtained with minimal concern in relation to recall bias. Notwithstanding this, reporting accuracy is an important consideration in any self-reported survey, with potential for prestige bias (exaggerated catches) or even deliberate deception. Limited comparisons between diary and concurrent creel surveys have, however,

indicated strong alignment between catch rates and catch distributions providing validation of reporting accuracy.

Recognising problems with recreational fishers estimating fish size and weight, diarists are routinely only required to report catch numbers. Creel surveys and/or a sub-group of reliable diarists, who also measure their catch, are used to assess mean lengths and weights, the latter being applied to convert catch numbers into weights.

Summary

The telephone-diary survey method has been successfully applied to provide reliable 'big picture' information about recreational fishing in a cost effective manner. For general fishing surveys, the level that such information can be reliably disaggregated, be it by method, species or region, is dependent on the relative importance of the fishery component in question. For rare or localised fisheries, targeted sampling of the sub-component of the fisher population of interest (e.g. through regional sampling, sampling other datasets including fishing licence and boat registers) may be required to improve data reliability. Alternatively, other survey methods may be more appropriate. There is, of course, no single survey method that represents a panacea and can address all potential research or management questions and there will always be constraints on research budgets.

The evolution of recreational harvest estimation in New Zealand from indirect to direct approaches

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The first considered attempts to estimate recreational harvests in New Zealand were regional telephone/diary surveys, which produced plausible estimates. Concerns were initially raised about one aspect, fish weight data supplied by diarists, but this was easily rectified by conducting parallel creel surveys in future attempts. In the first national telephone/diary survey, in 1996, a small scale parallel aerial access programme yielded comparable results, leading to further confidence in this approach. Pilot surveys conducted in preparation for sophisticated national surveys in 2000 and 2001 detected and quantified a previously undetected source of bias. Harvest estimates became implausibly high when corrections were made for this bias, and the method is no longer considered reliable.

Numerous sources of potential bias have now been examined, and because of their conflicting and often inestimable nature, these are considered irreconcilable. This has lead to a shift in focus towards observation based methods which can be used to estimate the harvest in a more direct manner. These methods give plausible results, which have undergone rigorous scrutiny. Several sources of bias have been identified but there is no evidence to suggest that most estimates are significantly biased.

Angler licence sampling frames - how can they be used to improve survey designs and reduce costs?

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Large-scale, off-site surveys of recreational fishing require cost-effective and representative sampling of the target population. This is often achieved by sampling households from 'White Pages' telephone listings. In Victoria, where an estimated 18% of households participate in recreational fishing, this screening process represents a substantial cost. When recreational fishers are licensed, there is potential to use a list of licence holders as a sampling frame. An all waters Recreational Fishing Licence (RFL) with age and concession exemptions was introduced in Victoria during 1999. An average 225,000 licenses are sold each year and, although around 60% of all fishers are exempt, RFL holders are major participants in key recreational fisheries. In the National Recreational and Indigenous Fishing Survey (NRIFS 2000-01), licensable anglers accounted for 95% of the recreational catch of snapper (*Pagrus auratus*), with most snapper anglers residing in Melbourne (79%) or statistical divisions along the Victorian coast (14%). Moreover, highly avid anglers (>15 days fishing annually) dominated the snapper harvest (81%), while comprising only 30% of fishers.

For the Victorian snapper fishery, the database of RFL holders was identified as a cost-effective sampling frame for a screening survey and subsequent 12 month diary survey to estimate total recreational catch. In 2006/07, this sampling approach was employed to RFL holders from coastal areas, along with specific over-sampling of avid fishers in the diary phase, to assess recreational catch and effort of snapper and other key marine species in coastal Victoria. The survey achieved improved precision for total catch estimates at a regional scale when compared to the NRIFS. A concurrent on-site survey assessed behavioural differences of 'out-of-scope' anglers, with the majority (65%) of snapper being harvested by RFL holders with a 'White Pages' telephone listing. Of the remaining 35%, the majority (21%) was attributable to RFL holders without a 'White Pages' listing, but their catch rates were very similar to their 'in-scope' counterparts. Consistent with the findings in the NRIFS, minority harvest levels were attributed to Victorian residents with a RFL exemption (10%) and inland Victorian residents (4%).

SESSION FOUR - RECREATIONAL FISHERIES RESEARCH AND MANAGEMENT IN 2028

WHAT SHOULD SUSTAINABLE RECREATIONAL FISHERIES LOOK LIKE IN 20 YEARS AND HOW DO WE GET THERE FROM HERE?

Overview

The final session gave representatives from a range of organisations an opportunity to present their vision on what sustainable recreational fisheries should look like in twenty years. The aim was to get presenters to reduce their focus on current issues, and instead consider their long term goals. If some common elements of these goals could be identified, then a strategy for getting there would be very worthwhile discussing.

From the representatives of the recreational fishing groups, the strongest theme was that anglers needed to be part of the solution. Examples were given of anglers participating in programs to improve the handling of released fish (by developing codes of practice), and contributed to habitat rehabilitation. The other theme was access, which still plays a dominant role in such forums. Anglers are very concerned about having access compromised by strategies such as multi-use spatial management as applied in marine parks.

Government speakers outlined issues associated with habitat management, the broader scope of marine parks, the importance of legislative requirements and the need for probability-based sampling to get representative data on recreational fisheries. The question and answer session was varied and included comments about the role of anglers within the freshwater allocation debate, non-fishing impacts in marine parks, the strengths and weaknesses of stakeholder-based data collection programs, and issues associated with property rights for recreational fishers.

In the year 2025….will recreational fishing be alive…

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In the song “In the year 2525 ….if man is still alive….” Zager and Evans painted a gloomy-optimistic picture of our future. Changing that to “In the year 2025….will recreational fishing be alive…..” here is a gloomy-optimistic picture of the future of recreational fishing.

- Participation will steadily fall as older fishers stop fishing or fall off their perch. The rate of younger people joining the ranks of fishers is not keeping pace with the attrition rate.
- Fuel prices will focus fishing effort closer and closer to population centres where catch rates are the poorest.

- As climate change bites freshwater will be allocated more and more to human use and flows of freshwater to the marine environment will be reduced which in turn will reduce fishing opportunities and fish stocks.

- More and more areas will be off limits to fishing as the area under no fishing marine protected areas increases. There is no certainty that these areas will spill over stocks that become available to fishing.

- Fish welfare groups will continue to constrict fishing practices such as live baiting. Anglers had better get proficient at using non-toxic, biodegradable soft plastics.

- Illegal fishing activity will increase as the price of seafood and the cost of going fishing escalates.

- A "business as usual" approach will ensure the gloomiest aspects will become reality, so some new approaches are needed.

- Recreational fishers have to become part of the solution rather than being seen as the problem.

- Younger fishers need to get off their backsides and become champions for the cause. Older fishers won't have to live with the consequences and therefore have no imperative to drive change.

- Modern flexible "virtual fishing organisations" need to be developed that function around the Internet and are savvy on how to engage politicians and the media. Our tired old structures are rapidly becoming irrelevant.

- Recreational fishing is a healthy pursuit that helps people cope with the pressures of modern day living, offers alternatives to drugs and computer games for kids, is an important social and economic activity for regional and rural communities and should be promoted as such.

- In the year 2025….recreational fishing can still be alive….but only if we change the way we do business.

A grass roots perspective – more fish and more access

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Question - What should sustainable recreational fisheries look like in 20 years, and how do we get there from here?

The state's recreational fishers answer to this question is simple and succinct. We want more of our target species in public waters, and greater access to them. Now, how we get there may not be as simple. So in paving the way along this pathway, here are our key stepping stones.

1. Currently, and in some cases, we have unnecessary restrictive, unscientific and even punitive methods of management and restricted access, including the so-called sanctuary zones.

2. The notion that one size fits all in terms of management is simply that – a notion! We propose a use of bioregional management and much greater emphasis on local knowledge.

3. Recreational fishers are unanimous in requiring management to be based upon sound scientific research with positive leadership and effective communication – not political expediency!

4. We want to increase suitable habitat by artificial and rehabilitation means, i.e. recreational fishers taking a broader role in environmental management.

5. The role of aquaculture should be enhanced and subsidised.

6. We call for the protection of spawning aggregations and spawning sites for species scientifically assessed as recruitment overfished or when the stock recruitment relationship indicates this type of management is appropriate. The size of the spawning stock allowed to spawn is critical.

7. Stocking programs can clearly provide more fish (Matt Taylor's Mulloway Program is a classic example).

8. Voluntary buyout of more commercial fishers.

9. Recreational fishers are adamant they want a radical restructure of the ministerially appointed ACoRF to make it truly democratic and truly representative.

Recreational fishers are keen to take a more proactive role in fisheries management at local and regional levels. It gives a concept of some ownership of the resource.

Inherent in this requirement is that traditional fishing knowledge held by ardent local recreational fishers, be recorded and documented. We are firmly of the view this expertise and knowledge would be invaluable for use in management decision making processes. We even endure punitive methods of fisheries management these days. An undersized fish taken outside one of the government's marine parks will attract a financial penalty of a two hundred dollars. The same fish, taken only a few metres away in the marine park will incur a penalty of five hundred dollars. We believe that's purely punitive.

And since 1997, we have had imposed upon us, unscientific management tools in the government's marine parks. As an example, a sanctuary zone that is 5km long and 4km wide around a tiny pimple of rock to protect a handful of grey nurse sharks, that may or may not stopover on their annual winter migration. What's scientific about that?

We have 56% of the same government marine park made available to commercial prawn trawlers to use every night of each week all year. Yet family off-shore recreational fishers from Byron Bay get to

use only 0.01% of the same park – and only for four months of the year. Where is the science in that in terms of conserving the biodiversity?

Regarding access! During the last decade we have witnessed the creep of coastal National Parks and Nature Reserves to the mean low water mark, thereby restricting vehicular access.

One brief typical example from the South Coast of NSW at Lake Merro. National Parks and Wildlife Service attempted to close off a designated road reserve of several kilometres, giving fishers, vehicular and boat access to the lake. Have they ever attempted to tow a boat and trailer by hand and on foot for kilometres? So ladies and gentlemen, these issues raise another fundamental question – just who is managing NSW fisheries? And recreational fishers have strong views about that too! And, those views don't involve the Department of Environment and Climate Change.

So that is what we, as sustainable recreational fishers, consider the fishery should look like in twenty years time, and the stepping stones needed to be taken to get there.

Australian fishing media's vision of sustainable recreational fisheries in the 2030's

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In 20 years we'd like to see a thriving and sustainable recreational fishing industry in Australia underpinned by the following characteristics:

- Angler's rights to fish are recognized and animal welfare issues have been addressed. In turn anglers are better educated on issues relating to sustainable fishing, as well as handling, releasing and keeping fish for the table.

- Ready availability of quality recreational fishing experiences in both natural and artificial settings (artificial reefs, stocked impoundments) where anglers can enjoy clean, healthy aquatic environments and have a reasonable chance of catching quality fish of a variety of species. Particular attention is made to providing quality landbased options for less affluent anglers.

- Access to well managed trophy fisheries (preferably in recreational-only fishing areas), where there is a reasonable chance of anglers catching large specimens of high value species such as mulloway, kingfish, barramundi, snapper, murray cod and so on.

- The economic value of recreational fisheries to the economy (including the value of released fish) is quantitated and updated on a regular basis.

- In recognition of their high ratio of recreational vs commercial economic value, a range of species are categorized as "recreational only", including tailor, longtail tuna, queenfish, mangrove jack and billfish.

- Minimum and maximum size limits, bag limits and marine parks provide significant sustainability benefits to fish populations and are not perceived as disincentives to go fishing
- Representation of the industry is funded by the industry and effective, united efforts can be initiated on issues which require lobbying of state and federal governments.
- Recreational fishing R&D is directed and partially funded by the industry with significant government support in recognition of the economic value of the sector to the economy.

Future sustainable game fishing for pelagic species – considerations

Grahame Williams

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GFAA is the National controlling body for recreational game fishing in Australia representing approximately 8600 affiliated members through seven State and Territory Associations. The role of GFAA involves management of fishing rules and equipment regulations, policy making, administration of Australian game fish species and records and liaison with Commonwealth and State fisheries agencies.

This presentation is aimed at providing information on the background of GFAA, where we are today and what we believe is required to maintain a sustainable game fish fishery into the future. The way that Governments, fisheries agencies, management and science can assist in the process will also be discussed.

Tools such as fishing methods, tag and release programs, size and bag limits and spatial management will be reviewed. Scientific knowledge of the recreational take is considered to be a key factor in achieving sustainability in the future. How can we manage these stocks when we do not know what the take is? Recreational fishing effort and possible effort increases through population growth may also have impacts on our management decisions in the future. Pelagic species do not recognise borders, therefore management of the stocks needs a common approach.

Recreational fishers: the champions for fish habitat rehabilitation?

Liz Baker

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Recreational fishing is recognised as the most popular past time in Australia, with NSW having the highest number of recreational fishers. In some areas of NSW, one in four people identify themselves as recreational anglers.

To anglers fishing in coastal NSW actually catching a fish was rated as the second most important attribute of a fishing experience. The highest priority for fishers was fishing in an unspoiled

environment. Unfortunately for many anglers enjoying that particular experience in NSW would be quite rare. Over the last 100 years the river systems of NSW have been highly modified and as a result there has been significant decline in the health of riverine ecosystems and in the abundance and distribution of native fish populations.

Even though an unspoiled environment rated highly amongst NSW recreational anglers, only a small proportion of individuals and clubs are proactive in enhancing or rehabilitating fish habitat - unlike their counterparts in countries such as the UK, Canada or the USA. Understanding the reasons for this relative lack of involvement and increasing the involvement of recreational fishers in fish habitat rehabilitation are core concerns of NSW DPI's Conservation Action Unit. While we are working with various industry partners on a suite of small programs, these largely focus on providing appropriate habitat related extension information. We see the need to build long-term partnerships between the large recreational fishing community of NSW, state government agencies and the regulatory bodies of recreational fishing.

Through the establishment of this partnership, trust between stakeholders will develop which will allow significant gains to be made for aquatic environments and fish habitats in NSW. Common goals in the future of the management of our native fisheries resources will be more openly discussed and strategies and/or solutions more easily obtained. The aim: to all be making more fish naturally!

MPAs vision for the future is focused on conservation of marine biodiversity

Brendan Kelaher and Adrian Toovey

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NSW Marine Parks represent our contribution to the National Representative System of Marine Protected Areas, honouring commitments to the Intergovernmental Agreement on the Environment and to the International Convention on Biological Diversity. NSW Marine Parks form part of a global representative system of marine protected areas aimed at ensuring long-term conservation of marine biodiversity around the world. NSW Marine Parks are not designed to facilitate fisheries management, but to enhance existing measures to protect the integrity of NSW coastal ecosystems. Secondary flow-on benefits to recreational fishers could, however, be realised by (i) commercial fishing buy-outs to re-adjust fishing effort, (ii) maintenance of size, age and genetic structure of resident fish populations and (iii) spill-over effects. The MPA's vision for the next 20 years and beyond is for the maintenance of marine biodiversity and ecosystem function in NSW, which can only be achieved through the implementation of complimentary current and future environmental legislation (e.g., Marine Parks Act 1997, Fisheries Management Act 1994, Environmental Planning and Assessment Act 1979, Catchment Management Authorities Act 2003, etc).

Research challenges arising from differing stakeholder objectives and perceptions

Aldo Steffe

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Introduction

Conflict over resource sharing, the allocation of fisheries resources and concerns about the sustainability of fish stocks have been present since at least the late 1800's in NSW. The Fisheries Inquiry Commission of 1880 was established to "make a diligent and full investigation into the actual state and prospect of the Fisheries of the Colony, the best means of developing and preserving them, the expediency of encouraging Pisciculture, or of supplementing the natural supply by the introduction and acclimatization of useful foreign species, and upon all matters bearing upon this subject". Prominent commercial and amateur fishers from that period provided testimony to the inquiry on a range of topics that included: the type of fishing they did; the areas they fished; their observations of seasonal fish abundance and spawning; their opinions on the status of the fish stocks and the causes of the declines in local fish stocks; and finally, their suggestions for addressing these concerns and improving the supply of fishes.

It is interesting that the management options proposed in 1880 are much the same as those being debated now. The commercial and amateur fishers from 1880 commented on unsustainable commercial fishing practices, the destruction of large numbers of juvenile fishes, the need to reduce populations of the enemies of prized foodfish (e.g. sharks and cormorants) and spatial management. In particular, many fishers suggested that seasonal closures and/or a system of rolling closures in which different fishing grounds were spelled routinely by rotation would aid the recovery of the local fish stocks. Today, we use bycatch reduction devices and minimum legal lengths to minimise the fishing-related mortality of juvenile fishes. We still strive to eliminate unsustainable fishing practices. We are increasingly allocating access to fisheries resources along sectoral divisions (e.g. estuarine Recreational Fishing Havens in New South Wales and the commercial closure in the Perth metropolitan area in Western Australia). Also, we continue to struggle with temporal and spatial closures (e.g. zoning issues related to Marine Protected Areas within Marine Parks).

The simple conclusion derived from this historical comparison is that all stakeholder groups (past and present) want sustainable fisheries but they differ on preferred management options to achieve the goal of sustainable fishing into the future. Regardless of the management options that are implemented it is important to test the effectiveness of the management initiative. The fisheries scientist is usually given this task knowing that the various stakeholder groups have different views and that they all want to have scientifically defensible information to support their position. This is true across sectors (commercial and recreational) and within sectors (i.e. there are many different groups within each sector).

This brings us to two key questions:

1. What implications does this need for scientifically defensible data have for the scientist?

2. What are the emerging research challenges?

I discuss five main points which, in my opinion, encapsulate the implications for researchers and identify the emerging research challenges that lie ahead.

Implications for Researchers and Emerging Research Challenges

Representative data

The implementation of sound scientific methodology is the most important consideration for any researcher with respect to designing a cost-effective recreational fishing survey that collects data that are representative of the entire fishing population in the area of interest. That is, it is vital that recreational fishing data be collected using probability-based survey designs. Biased or unrepresentative data collection can occur in many guises. For example, consider a project that aims to document recreational catch and effort in an area or even to simply monitor trends in recreational catch rates of avid anglers in an area. The data are then collected in an ad hoc manner by simply accepting information via a web-based forum from anyone who is willing to provide it. This sampling approach may generate a large sample and appear to be cost-effective, however, this information is seriously biased towards those avid anglers that have internet access and have caught fish. These biased data cannot be used to make inferences about the general angling population or of the status of the fishery in the area of concern. These data cannot even provide general insights about the catch rates of avid anglers because: (a) these anglers are much less likely to report zero or low catches; and (b) the fishing characteristics of avid anglers that do not have internet access are likely to differ from those anglers that have provided the sample. The message is twofold: (a) it is imperative to use probability-based sampling methods because they provide protection against biased data collection; and (b) it is wise to maximise sample size but this is only relevant when the data collected are representative. When data are biased they are inaccurate and the effect of increasing the sample size is to make the data precisely inaccurate.

Reversal of the burden of proof

Precautionary management of any wild resource requires a buffer for uncertainties to safeguard the future health (sustainability) of the fish stock or ecosystem. Reversing the burden of proof has been suggested as a method for providing this buffer (Peterman 1990, Mapstone 1995, Underwood 1997). This means that it cannot be assumed that a fishing activity is benign simply because there is little or no information available to formally test the assumption of no impact. Instead, the onus has now been shifted to the proponents of development and/or resource user groups (i.e. recreational fishers in this specific example) to show that they do not have an unsustainable impact on fisheries resources. This reversal of the burden of proof is designed to minimise the frequency of Type II errors (i.e. failure to detect significant impacts when they in fact do occur) so that statistical errors should favour the long-term sustainability of the fishery. The consequence for researchers is that they will need high levels of replication to ensure that any fishery-related impacts on the resource can be detected. This will, of course, increase the cost of surveys. However, should highly replicated and

statistically powerful survey designs be absent, it will be necessary for fisheries managers to make decisions in a precautionary framework to ensure that fisheries are sustainable. A precautionary framework has to assume that recreational fishing has unsustainable impacts on the resource. Clearly, this is an undesirable consequence for recreational fishers and it would be prudent to invest additional funds towards data collection so that fisheries managers can make decisions based on scientifically defensible advice rather than predetermined and politically mandated solutions.

Developing cost-effective ways of collecting representative data

There is clearly a need for researchers to investigate novel and cost-effective ways of collecting representative data. The solutions to this problem are likely to differ depending on the spatial scale of the proposed survey. The greatest challenge lies in the cost-effective estimation of recreational effort and catch over a large spatial scale (e.g. statewide or national). A recent review of recreational fisheries survey methods by a committee of international experts offers some possible solutions (Committee on the Review of Recreational Fisheries Survey Methods 2006). This panel of experts reviewed existing survey methods with a view to improving the methodology used in the Marine Recreational Fisheries Statistical Survey (MRFSS), a survey intended to provide national estimates of the recreational effort and catch of saltwater fishers in the United States of America. A major recommendation arising from this review was that a comprehensive, universal sampling frame with national coverage should be established. This universal frame was to be achieved "through a national registration of all saltwater anglers or through new or existing state saltwater license programs that would allow no exemptions and that provide appropriate contact information from anglers fishing in all marine waters, both state and federal." (p. 5 Committee on the Review of Recreational Fisheries Survey Methods 2006). Importantly, this system allows certain groups (e.g. pensioners, children) to continue to fish for free as long as they are registered in the universal sampling frame. The Review Committee also pointed out that "an updated, complete registration list would greatly improve sampling efficiency in terms of time and cost. Although these savings might not cover the entire cost of maintaining such a database, the benefit from the increased quantity and quality of the data would be worth the extra cost, especially if there is an associated increase in public confidence in the final estimates." (p. 6 Committee on the Review of Recreational Fisheries Survey Methods 2006).

Some states in Australia have implemented a recreational fishing fee (New South Wales) or a licence system for some recreational fisheries (Victoria, Tasmania, Western Australia). These recreational licensing systems do not provide a complete list of all recreational fishers participating in those fisheries because of various exemption categories. Within Australia, the establishment of comprehensive statewide and/or national registers of recreational fishers would supplement existing licensing systems and can be expected to deliver similar benefits to those described for the fisheries of the United States of America, whilst also providing a valuable tool for fisheries agencies to facilitate communication and consultation with their recreational stakeholders.

At regional and local spatial scales, the use of new technologies for monitoring fishing effort show great promise for providing cost-effective solutions to survey problems. For example, the deployment of automated traffic counters at boat ramps has been used successfully to improve the accuracy and precision of effort and catch estimates within an estuary (Steffe et al. 2008). This type of effort monitoring can also be expected to work well on a regional scale. Similarly, the use of web

cameras and artificial neural network software have great potential value for reducing costs associated with regional monitoring of boat movements at many choke points in a fishery, such as at entrance areas that connect estuaries to the ocean.

At all spatial scales, power analyses of past survey data are useful for designing more cost-efficient future surveys (Peterman 1990, Hoenig and Heisey 2001).

Involvement of volunteers and anglers in research programs

There is a growing trend for fisheries agencies to involve volunteers and anglers in research programs (e.g. filling out logbooks describing their fishing trips or interviewing other fishers during recreational fishing surveys). This is done for a variety of reasons that include: improving public relations; increasing education and awareness of important issues among recreational stakeholders; the enthusiasm and labour provided by volunteers allows the collection of additional data; and stakeholder support and cooperation is needed to run successful surveys. Therefore, the use of volunteers is often seen as a cost-effective way of collecting data and empowering recreational stakeholders. However, there are two major issues that are rarely acknowledged but need to be considered when involving volunteers and anglers in research programs. Firstly, the management of a volunteer work force requires a large investment of resources (time and money) and the researcher must have superior organisational and inter-personal skills to reduce turnover in the ranks of the volunteers. Secondly, the utility of volunteer generated data can be easily compromised. This can occur when volunteers cannot understand or refuse to follow instructions and revert to *ad hoc* unrepresentative data collection. This type of problem is difficult to detect during the data collection phase of a survey and may introduce serious bias into the results of a survey. For these reasons, I recommend that volunteers involved in research programs need to be supervised by a scientist trained in probability-based data collection.

ESD-based indicators of fishing quality derived from surveys

Important management decisions relating to the allocation of shared fisheries resources and the assessment of sustainability for recreational fisheries are made difficult by: (a) the expense of collecting information for large recreational fisheries that have diffuse access; (b) the paucity of quantitative information available for most recreational fisheries which also weakens stock assessments; and (c) the lack of work aimed at determining reliable and robust ESD-based indicators of recreational fishing quality for different fisheries.

There is a national need to develop reliable ESD-based indicators of recreational fishing quality for each major type of regional recreational fishery (eg. charter boat, gamefish, marine trailer boat, ocean rock and beach, estuarine, and various freshwater fisheries). These indicators should provide a cost-effective way of monitoring the relative quality (status) and sustainability of important regional fisheries. The development of ESD-based indicators of recreational fishing quality should be derived from existing survey information that has been collected by various fisheries agencies. These historical data could be used to provide fishing quality benchmarks for different fisheries. The development of these ESD-based indicators provides a cost-effective way of assessing the status of recreational fisheries through time. They also have the potential to provide an improved and easily understood method for communicating complex information to stakeholders.

Conclusions

I have written this critique from the point of view of an active researcher. I have identified five main points that summarise the emerging research challenges and the implications for researchers working on recreational fishery issues. The challenges for researchers are: (a) to use survey methods that are probability-based to ensure data are representative (unbiased); (b) to consider a precautionary framework (reversal of the burden of proof) when designing surveys so that the level of replication within surveys is maximised; (c) to develop cost-effective ways of collecting representative data. Angler registers offer a possible solution for addressing recreational fishery issues over large spatial scales; (d) to involve volunteers and anglers in research programs but only when supervised by a scientist trained in probability-based data collection; and (e) to develop ESD-based indicators of fishing quality for a variety of different fisheries. These ESD-based indicators can provide important benchmarks for assessing changes in recreational fisheries through time. The indicators should be derived from existing survey data held by different fisheries agencies.

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ASFB President - Summary Remarks

Patrick Coutin

Before I begin to sum up the workshop outcomes, I would like to take this opportunity to congratulate our hosts, NSW Department of Primary Industries, for a successful workshop and acknowledge the sponsorship support from the Fisheries Research and Development Corporation, West Australian Department of Fisheries and the NSW Recreational Fishing Trusts. On behalf of all the participants and the Society, I am very grateful for the work and commitment of the organising committee, James Scandol, Doug Ferrell, Charles Gray and others from the Cronulla Fisheries Research Centre of Excellence. Thanks also to all the speakers today and to the people who've chaired the sessions. It's been a very interesting and worthwhile workshop with outcomes that will provide guidance for some ways to progress the science of recreational fishery assessment and address the challenges in the future.

Historical Context

In August 1994, ASFB held a recreational fishing workshop in Canberra that focussed on the question "What's the catch?". Bob Kearney, the keynote speaker made a bold attempt to answer this simple question and set out the reasons for why we need to know such basic information about the recreational fishery in Australia (Kearney 1994). "In the short term", he said "improved knowledge together with accurate assessment and realistic interpretation of the impact of recreational fishing are pre-requisites for protecting and improving the quality of angling".

It might seem like a long time ago, but we've made some terrific progress since those days. And although there was some pessimism at this 2008 Workshop as we explored the details of how to conduct surveys and set research priorities with limited budgets, there can be no doubt that we are now in a much stronger position than in 1994 (Mcglennon 1994; Muoneke and Childress 1994; Pollock et al. 1994; Teirney 1994). After the 1994 workshop, many of the participants embarked on a range of recreational fishery projects that have now established monitoring baselines in several States (eg (Ryan et al. 2006; Smallwood and Sumner 2007; Steffe and Chapman 2003; Steffe et al. 2007; Vanderwalt and Faragher 2000). Together they collaborated in the design and implementation of the first National Recreational and Indigenous Fishing Survey (NRIFS 2000-01) (Henry and Lyle 2003). With these achievements and national coordination through ASFB's Recreational Fishing Committee, we are making significant progress in the science that underpins the large, diverse and valuable recreational fisheries in Australia. Compared to some other countries around the world, where there is very little information on recreational and indigenous fisheries, I would suggest that Australia is now in a much better position than it was in 1994 and the challenge now is to make further progress in recreational fishery assessment and to update the information obtained in the NRIFS 2000-01.

International Perspective

As before, we have had the benefit of hearing from our colleagues from USA, New Zealand and South Africa (Malvestuto 1994a; b; Teirney 1994; Vanderelst and Penney 1994). Martin Cryer and Bruce

Hartill from the Ministry of Fisheries and NIWA gave their perspective of the recreational fishery in New Zealand. With catch estimates of 25,000 tonnes, New Zealand has a reputation for some of the finest fishing in the world. The high value of the fishery is recognised and a wide variety of information is needed for management. Compared to most commercial fisheries, recreational fisheries are very complex and highly variable, which creates many difficulties for designing robust and cost-effective monitoring programs. Recreational fisheries are generally seasonal, often distributed over large spatial scales, and involve a large number of participants with varying levels of fishing skills and participation rates.

In New Zealand, the recreational fisheries are based on at least 60 species and 200 stocks. Bruce Hartill recognised that monitoring the recreational fisheries for these species was a difficult and complex problem that was not going to be solved easily. He discussed the many potential sources of bias in telephone based surveys and problems associated with extrapolations and total catch estimation. In New Zealand, aerial surveys have been used recently to make direct observations of angler effort which have produced more plausible results and there is no evidence of significant bias in total catch estimates after rigorous scrutiny of this approach.

Sandra Diamond from Texas USA provided a valuable insight into contemporary recreational fishery research in the USA and there are important lessons to be learnt. In 1994, Malvestuto outlined the methods used to estimate the recreational catch in the USA. These surveys have been conducted every 5 years for 25 years and have cost a lot of money. With over 14 million anglers in the USA, fisheries managers are becoming increasingly concerned about the impacts on many fish stocks and are seeking better ways to assess the recreational fisheries (National Research Council 2006). However, the take-home message from Sandra was that even with the considerable expertise and substantial investment in the USA, the techniques and sampling frames used for assessing the recreational fisheries are still not quite right and a panel has recommended a complete re-design for the Marine Recreational Fisheries Statistical Survey. The science behind recreational fishery surveys is hard and difficult to do correctly so the results need to be validated. New techniques such as vessel monitoring systems and electronic logbooks offer more advanced approaches that have potential for validation and may help to improve catch and bycatch discard estimates.

In Australia, we have experienced similar difficulties and criticisms of the first National Recreational and Indigenous Survey (NRIFS 2000-01), and by working with the scientists from the USA and New Zealand together we can tackle some of the difficult issues that are fundamental to recreational fishery research. ASFB has contributed to the scientific progress and played an important role by supporting the collaborative network and by sharing contemporary information at meetings and workshops. Since 1994, the Recreational Fishing Committee, now chaired by Aldo Steffe, has had a key role in national and international co-ordination and this collaboration needs to continue in order to avoid costly mistakes, improve survey techniques and enhance recreational fishery assessment (Bradford 2000a and b; Bradford 2002).

Social and Economic Importance of Recreational Fishing

Another very important point that was made was the emphasis on the social and economic importance of recreational fishing. As a pastime, it is part of the coastal and inland life style and an

essential part of Australia's modern culture and traditional heritage. However, although the socio-economic significance of recreational fishing to the nation is now recognised, based on the results of the NRIFS 2000-01 (Henry and Lyle 2003), as Bob Kearney says "we still don't know how to value it." Everyone knows it's important but when we try to compare recreational fishing to other types of primary industry, tourism or coastal development, the community social and economic values for different sectors can not be adequately quantified and compared directly.

Expenditure data that was collected during the NRIFS 2000-01 showed how much anglers spent per trip on more than 45 categories of goods and services. Other data was collected to show fisher motivation, how many people were involved in the recreational fishery, age group, gender and country of origin, how much time was spent fishing and how many fish were caught and discarded. Much of this socio-economic information has a wide range of uses but fundamentally it is easy for politicians and the public to understand. Now that everyone knows and accepts that there are a large number of anglers who spend a lot of money as part of their recreation and leisure activities, it is time to move forward and up to the next level to quantify it and put the values into context.

Other issues that are much harder to value need to be considered according to Bill Sawynok, such as the health benefits not only from eating fish but the leisure activities that people enjoy while fishing and being outside whether it is camping by a river, a lake, the coast or being on the water in a boat. These community values need to be taken into account, but social values are very difficult to measure scientifically and compare with economic values in other sectors. Recreational fishing is a deep intrinsic part of the coastal community activities in Australia and New Zealand. As Bob Kearney says and rightly, 'we need to evaluate and allocate the benefits of fish and fishing correctly,' not just for the recreational fishery but also for the seafood consumers who don't catch it themselves but enjoy the cuisine and health benefits of eating seafood whether it be as residents or as tourists.

The NRIFS 2000-01 was a very important achievement as it provided a national perspective and firmly established the size and significance of the recreational fishery in Australia. This information has been widely used in many contexts, but as Len Olyott noted, "It was a good start, but now it is out of date so more accurate and up-to-date information is needed to avoid a culture of misinformation". Periodically the national survey needs to be repeated with improved methods, higher sampling intensity and with validation. The science behind the national survey needs to be robust and reliable so that people can have confidence in the results. The design and cost of the survey depends greatly on the questions being asked. However new questions quickly emerge and the data used for many different purposes that the survey was not designed to address. Eventually another survey will be necessary to meet the information needs of the managers, industry and the public. However, as time goes on each new survey will be compared with the first one to assess the long term changes in the recreational fishery.

Bob Kearney also called for genuine and open consultation and suggested that a greater effort is needed to work together to achieve co-management and to get over some of the difficulties of the past. Some anglers simply don't trust the survey data or maybe they don't understand how it was collected nor have access to it. Randall Owens from GBRMPA agreed that there was a need for co-management and good communication at the local level, particularly in relation to monitoring the

impacts and effectiveness of spatial zoning. Bill Sawynok's programs are an example of co-operative research at the community level that was helping to improve local and regional management.

Patrick Hone and Bob Kearney emphasised the need to collect sound and reliable scientific data on the recreational fisheries so it can be incorporated into assessments. Generally since 1994, the data has been used mostly for descriptions of recreational fishing, quantifying the catch, monitoring species compositions and catch rates. In Queensland, tagging data has been collected for many years and now fishery monitoring, biological monitoring, age composition data is being collected. The next step is to use the recreational fishery data to improve stock assessments and fishery management eg (Mcdougall et al. 2008; Stewart 2008). A good example of this approach is described in a recent paper on Murray cod assessment (Allen et al. 2009).

Scientific Improvements in Recreational Fishery Assessment

Clearly, the science behind recreational fishery assessment is improving as more investment is being put into recreational research and monitoring by FRDC and the State agencies. ASFB members are playing a pivotal part in fostering research co-operation and information exchange in this rapidly evolving aspect of fisheries science (Broadhurst et al. 2005; Davey et al. 2007; Frisch et al. 2008; Hoyle and Cameron 2003; Lyle et al. 2002; Sumner 2006). It is vital that the monitoring methods are improved and consistent between states. By working together we can develop cost-effective, statistically robust methods for assessing recreational fisheries so trends can be tracked over time. We need to convey key messages to the public and provide the information not only for management but to angling community as well. This workshop and the proceedings will help with that communication.

Major Outcomes

There were four major outcomes from the workshop on how we can improve recreational fishing research in the future.

The need for a licence system to create a robust sampling frame

It is politically sensitive but from a scientific point of view, there are compelling reasons for the States and the Commonwealth to develop comprehensive angler and charter boat licence database systems. In addition to the revenue that is needed for recreational fishery research and management, a licence database provides the most accurate and cost-effective means for conducting angler surveys and assessing recreational catches. A recreational licence database is a fundamental progressive step forward for fishery management that will enable direct communication and data collection from an unbiased sample of anglers. The potential benefits for research, management, education and enforcement are substantial. This issue was discussed at the 1994 workshop and since then there has been some progress in several states. However, more development is needed to create an effective sampling frame from recreational licences as the data needs verification so that all contact details are correct and accessible to researchers in a database. The technology is widely utilised in business for communication with customers so it would not be difficult to adapt their methods for managing an angler licence database. For a complete sampling frame incorporating all anglers, the licence system may need to allow the issue of free licences to

some people in the community who are currently exempt, such as children, pensioners and others. It would also have to accommodate travellers and tourists.

Clearly, from the experiences of scientists working in the USA, New Zealand and Australia, a better sampling frame would make recreational fishery research so much more cost effective and more robust in terms of the statistics, consistency, comparability and continuity. Where licence systems have been implemented, scientists have used them for routine monitoring and fishery assessment. Without a licence database, scientists will rely on the household survey method as in the past, but the costs are high so the sampling intensity is low and it is unlikely that surveys will be conducted frequently. It will be difficult to determine recreational fishery trends without regular surveys making fishery assessment and management less precise and less effective. So, an important consideration for the future is to determine what needs to be done to achieve a universal angler register, either at State level or Federal level? It has been clearly identified as a priority in the Recfishing Research Plan 2009/10, so hopefully funding will be made available in the future.

Traditional and novel methods of measuring recreational catches need validation

The need for validation of estimates of angler's catches was emphasised by Bruce Hartill from his research experience in New Zealand. Small errors or bias in estimates of catch rates or size composition from insufficient sampling or poor survey design are magnified by the large values of fishing effort. By cross-checking and validating the data, and not relying on just one method, scientists can ensure that the estimates are reliable and accurate. It is important to do this to give the managers and the public greater confidence in the results. In Victoria, NSW, Tasmania, South Australia, Western Australia, the Northern Territory and Queensland, ASFB members are starting to fill some of the gaps that were apparent in the results of the national survey. The recreational catch estimates and fishery assessments will improve as more basic data is collected routinely to estimate the size of fish caught and differences between the avid anglers, charter boat anglers and non-avid anglers. I am confident that some of the problems that have occurred in the past will be readily addressed in the future to improve the survey techniques.

Innovation and the application of new technology

In 2006, the ASFB Workshop addressed the opportunities for adopting cutting-edge technologies in fish and fisheries science. There was a session on data capture and management that included cost effective techniques for monitoring recreational fisheries in Western Australia (Brent Wise) and vessel monitoring systems (Peter Stephenson). There are many new ways for scientists to utilise technology in recreational fishery research and this represents an exciting frontier where innovation can yield great benefits if there is investment in the technology. Applications that have potential in recreational research include: the use of videos for monitoring boat numbers, traffic counters at access roads to boat ramps, tagging techniques used to measure the recreational catch, innovative licence systems, GPS linked electronic log books and web-based data collection. Innovation and the application of new technology need to be explored and funded to improve scientific capability in recreational fishery research.

Collaboration and support from anglers and the recreational fishing industry

Researchers already know that collaboration with the angling community is essential but maintaining good relationships requires a great deal of effort and good relationships are often compromised by unpopular management decisions, such as the establishment of marine parks, or mis–information. Effective engagement with the angling community, not only assists greatly with receiving public support for funding allocation, but may lead on to active co-operation in the research and the management of their fisheries. Anglers can help greatly by advocating for the restoration of fish habitats and by disseminating information. Anglers do love to gossip so providing the fishing media with up to date and accurate scientific information is one of the best ways to educate the angling community. The increasing use of angler diaries in research is leading to the development of time series of data provided by anglers that will enable the trends in recreational fisheries to be included in stock assessments and will help to improve management of the fisheries.

Conclusion

In Australia, the rationalisation of research has reduced scientific capacity considerably since 1994. The fundamental constraint to improving recreational fishery research is the level of funding and investment for the large, complex and very valuable recreational fisheries. Although many are politically aware of the significance of the recreational fisheries, there is currently no robust method of estimating the social or economic value and it is unclear whether recreational fishing belongs in primary industries, tourism, sport or social welfare.

In comparison to other primary industries, fisheries research is so much more complex because of the number of species involved, with many life stages distributed amongst a variety of dynamic freshwater, estuarine and marine eco-systems. For many of the important recreational fish species, even the iconic species, there is a fundamental lack of basic biological information and yet we're trying to tackle complex management questions about the effects of fishing and sustainability, as well as looking ahead to try and deal with climate change – the theme for the 2010 Workshop in Melbourne. Recreational fisheries research is even more difficult because of the number of people involved, the range of skills and equipment, rapidly changing technology, the variety of fishing locations and the variability in the catch and species targeting. The science is therefore very challenging and the Society has made a great contribution by bringing together the experts, fisheries managers, recreational fishery representatives and funding agencies at this workshop. With so many complex issues involved in recreational fisheries assessment, the commitment to develop long term strategies and improve research funding by the Commonwealth and States is essential. Investment in recreational fishery research is needed in order to collect consistent data sets, validate techniques and undertake the necessary monitoring for managing fisheries and protecting aquatic habitats and fish stocks. With sound scientific information, it is more likely that management strategies will maintain or improve the quality of angling in rivers, lakes, estuaries and the sea in the future.

From the discussions at this Workshop, it is clear that there have been many significant achievements in recreational fishery research in Australia and New Zealand since 1994, but there are some weaknesses and major threats to further improvement. The key points are:

- The information base has grown considerably and for some recreational fisheries, there is now more than 10 years of monitoring data which provide a basis for assessment and analysis of fishery trends.

- The first national survey was a successful collaboration and a baseline has been established using sound methods that can be repeated and improved with further investment.

- However, most recreational fishery data is collected sporadically, and these data are often geographically limited, incomplete or inconsistent. Different sampling methods are frequently used. There are also biases that need to be corrected or taken into account.

- Recreational fishery research and management must adapt and work together to address the emerging issues and challenges ahead, particularly the responses of fish and anglers to climate change and threats from overfishing, habitat degradation and water abstraction.

- There are many priorities set out in the Recfishing Research Business Plan that provides national direction. However, most of these are underpinned and dependent on good scientific research and fishery monitoring. In the future, there will be opportunities to enhance recreational fisheries by evaluating stocking strategies, assessing the effectiveness of management methods and improving anglers fishing practices. The science behind recreational fishery assessment will play a vital role in exploring for new ways to deliver better outcomes for anglers and evaluating the success of management strategies.

- Currently, there is a lack of robust indicators of the abundance of fish stocks based on recreational fishery data and reference points have not been established to bench mark the desirable quality of recreational fishing in Australia. The challenge for scientists, managers and the angling community is to agree on sustainability indicators for recreational fisheries and to work together in partnership to ensure that long term monitoring data is collected systematically to improve recreational fishery assessment and management in the future.

In the future, scientists, fisheries managers will continue to build better working relationships with recreational fishers as there is a need to be proactive in finding innovative and cost effective solutions that will improve both the knowledge base and the resource. Maintaining the status quo or reducing investment will not be effective in overcoming the problems of the lack of information, poor communication and frequent conflict that have occurred in the past. By developing effective partnerships with stakeholders, there will be greater co-investment, involvement and engagement with anglers, the tackle industry and charter boat operators. Co-operation in data collection will provide more information and is likely to assist in co-management and better outcomes for the recreational fisheries.

Future activities of the Australian Society for Fish Biology

ASFB has a key role to play in coordinating and helping to improve recreational fishery research. The Society is an international science network and the Recreational Fishing Committee is dedicated to improving research collaboration, advancing the scientific techniques and technology. The ASFB newsletter and website provide a gateway for distributing information to students, scientists,

resource managers and the global community. Hard copies of the Proceedings from this workshop will be widely distributed to members, sponsors, and libraries. Electronic copies will be made available through the ASFB website. Further scientific meetings have been planned between Australian and New Zealand scientists to encourage closer collaboration. Annual meetings of the Recreational Fishing Committee will enable further developments and review of survey data and assessment of recreational fisheries. There are also opportunities for international collaboration through the World Council of Fisheries Society at the next World Fisheries Congress to be held in Edinburgh in 2012 hosted by the Fish Society of the British Isles.

Acknowledgements

State and Commonwealth sponsors, particularly FRDC and MDBC, have supported the Society with funding and in-kind contributions of staff time and resources for many years. The ASFB Annual Workshop and Conference would not be possible without their ongoing support and the information published by the Society would not be available to the community. On behalf of the members and the Executive, I would like to express our gratitude to them as their support has allowed the Society to grow and prosper. Finally, thanks once again to all the speakers and the organising committee for making this 2008 ASFB workshop a success.

Patrick C. Coutin
President
Australian Society for Fish Biology

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The Australian Society for Fish Biology Conference 2008

THE ASFB 2008 CONFERENCE - WELCOME

We are pleased to welcome you to the 2008 Australian Society for Fish Biology Workshop and Conference. This year we have streamlined the annual event into three consecutive days; encompassing a one day workshop followed by a two day conference. The organising committee has selected iconic Bondi Beach as the workshop and conference venue. We trust this location provides an inspiring mixture of spectacular scenery, great culinary opportunities and a stimulating scientific environment.

The theme to this year's workshop is "Assessing Recreational Fisheries - Current and Future Challenges". We have developed a program that will: provide an overview of current policy direction, management strategies and research programmes; explore partnerships between recreational fisheries management and research; discuss existing and novel approaches for assessing recreational fisheries; and provide a forum for stakeholders to present their vision on what sustainable recreational fisheries should look like in 20 years. This workshop will be of interest to fisheries managers, scientists and industry and stakeholder representatives.

This year's conference has attracted a diverse range of oral and poster presentations that will be attractive to the wild field of interest and experience of participants. The program encompasses presentations ranging from the ecology of larval fish and links with oceanography to the reproductive biology and age and growth of fish and invertebrates, biology and ecology of freshwater fish and fisheries to resource assessments of coastal species, overviews of recreational fisheries management and research through to stock enhancement and artificial reefs. We are particularly pleased by the numbers and diversity of student presentations. The plenary session will feature Dr Jeff Leis, the current recipient of the K Radway Allen Award, and Dr Matt Taylor, the recipient of the ASFB Student Travel Award 2007.

We gratefully acknowledge the generous support of our sponsors for this year's event. In particular we thank the Fisheries Research and Development Corporation as the Principal Sponsor of the Workshop, and the NSW Department of Primary Industries as the Principal Sponsor of the Conference. We are confident that the Workshop and Conference will be an informative and stimulating meeting and we hope you enjoy your stay at Bondi Beach.

Charles Gray

James Scandol

Aldo Steffe

Doug Ferrell

PLENARY PRESENTATIONS

K (Kenneth) Radway Allen: A lifetime in fisheries science

Kevin Rowling

Cronulla Fisheries Research Centre of Excellence
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Kenneth Radway Allen (known to his colleagues simply as 'K') was born in London, on the 12th February 1911. The family settled in Todmorden, Lancashire, where his father taught mathematics, and K gained entry to Manchester Grammar School. During a term off school convalescing from an illness, he completed a survey of insects in a nearby stream, and developed a strong interest in freshwater biology. He later studied zoology at Cambridge University, specialising in aquatic insects, and in 1932 he graduated with a B.A. (Hons).

During his time at Cambridge, the Freshwater Biological Association (FBA) of the British Empire opened a laboratory in Wray Castle, on the shores of Lake Windermere, and K spent his university vacations there. He became more interested in the fish fauna that consumed the insects, and took up angling as a hobby. In 1934 he published his first paper, a modest 2-page description of the food of young perch, in a journal titled "Game & Gun & The Angler's Monthly". After he graduated, K was appointed by the FBA to study the biology of the freshwater phase of Atlantic salmon. While at Wray Castle he also met and married Rosa Bullen, the Director's assistant - Rosa was a lively, intelligent lady who would become K's lifelong partner in both his personal and professional pursuits.

In 1937 K was awarded his M.A. from Cambridge, and there followed a series of papers in the Journal of Animal Ecology on the biology of trout and pike from Lake Windermere, and also salmon from the Eden River in north-west England and the Thurso River in Scotland. However, he found he was unable to extend his research to other regions in the British Isles, because most of the rivers and streams were privately owned. So in 1938 K and Rosa moved to (her native) New Zealand, where he took up a position as biologist with the Fisheries Research Branch, Marine Department, based in Wellington. He soon determined that the Horokiwi stream to the north of Wellington would be suitable to study riverine ecology and the population biology of brown trout, and he and Rosa built their first home in the remote countryside near Lower Hutt. With Rosa as his assistant he undertook a detailed study of the Horokiwi, interrupted by a period of service with the New Zealand army during the war (1942 to 1946).

The study of the Horokiwi culminated in 1951 with the publication of a seminal 238 page report which was to lead to a more quantitative approach to ecological research. In the same year K became the inaugural President of the New Zealand Ecological Society, a position he

held until 1956. In 1964 he was elected an honorary life member, and he maintained a life-long interest in the Society.

K had been promoted to Senior Research Officer with the N.Z. Marine Department in 1946, and in 1961 he was appointed Director of Research of the Fisheries Research Branch. During this period he became interested in the theory and practical application of fish population dynamics in relation to fishery management. Initially his focus in this work was in terms of biomass, but this was to develop into much more detailed numerical population modelling in later years. K continued his interest in freshwater ecology, and published a series of papers in the Proceedings of the New Zealand Ecological Society, including the first Presidential address to the Society titled "The Growth of Accuracy in Ecology" in which he observed that ecology, being a relatively 'new' science, could not yet be termed an 'exact' science, but it was his view that it was very much moving in that direction with the development of more quantitative techniques. In the same year (1955) K also raised what he saw as the poor level of funding for research into the positive and sustainable uses of 'wildlife' in a paper titled "The Wildlife Problem - A Question of Values".

Disenchanted with a lack of departmental support for research in New Zealand, in 1964 K moved to Canada to take up a research position with the Fisheries Research Board of Canada at Nanaimo, British Columbia, initially studying the population dynamics of salmon and lemon sole. K was quick to realise the power that early computers could bring to numerical analyses, and he regularly drove the 150 miles to Seattle to use the newly installed computer at the University of Washington. Eventually an IBM 1130 Computing System would be installed at Nanaimo. Appointed program head of the "Anadromous Fish Investigations" group in 1965, K moved to St. Andrews on the east coast, where he continued population studies of Atlantic salmon, including the first analysis of the oceanic salmon fishery which had developed off Greenland. In 1967 he was appointed to the position of Director of the Fisheries Research Board of Canada, based in Nanaimo, and supervised all fisheries research on the Canadian Pacific coast.

In 1960 K had been invited by the International Whaling Commission (IWC) to be a member of a committee of experts (initially with Douglas Chapman and Sidney Holt, and later to be joined by John Gulland) to provide an analysis of the status of whale stocks and advise on the most appropriate future management arrangements. The detailed data sets held by the IWC provided a good opportunity for K to further develop his interest in numerical population modelling, and during a 25-year period he took a leading role in the Scientific Committee of the IWC, successively representing New Zealand, Canada and then Australia, and chairing the Committee from 1974 to 1979. This was also one of K's most productive periods for research output - between 1968 and 1988 he authored sixty papers and reports relating to the assessment and management of whale stocks, and a further twenty papers mainly dealing with aspects of salmon biology or methods for studying population dynamics.

In 1972, with the "winds of change in (people) management theory" beginning to blow harder in North America, K escaped to Australia to take up the position of Chief of the CSIRO Division

of Fisheries and Oceanography, based in Cronulla. He very much enjoyed this role, as he presided over a period of growth in the fisheries research capabilities of the organisation, including the construction of new laboratories at Marmion and Cleveland. He almost succeeded in acquiring a purpose built research vessel for the Division, until a change in Government just as tenders were about to be called led to the cancellation of the proposal. In 1973 K was awarded a Doctorate of Science from Cambridge University, in recognition of his outstanding research achievements in the fields of freshwater ecology, theoretical population dynamics and the analysis and assessment of whale stocks. He was particularly proud of this award, and was able to receive it in person while attending an IWC meeting in London.

After his retirement from CSIRO at the age of 66 in 1977, K maintained a very active interest in fisheries science as a consultant, and he continued to have significant scientific input into the IWC, the UN FAO and a number of fisheries research and management organisations in Australia, the United States and Canada. In 1978 K presented a series of lectures at the University of Washington on the assessment of the status of whale stocks, and this information was later updated and published in his 1980 book titled “Conservation and Management of Whale Stocks”. This publication summarised much of the research undertaken by the Scientific Committee of the IWC, which led eventually to the cessation of whaling in an attempt to rebuild the significantly depleted stocks. The underlying philosophy of this work was concerned with the proper management of renewable resources, and acknowledged the distinction between ‘conservation’ and ‘protection’ of whale stocks. Recent developments within the IWC demonstrate that this debate has shifted ground during the past two decades.

In the twenty years following his ‘retirement’ K completed a prodigious amount of research and analyses for a large number of institutions, and his productivity lasted well into his 90’s. In addition to his paid consultancies, K also found time to contribute to courses designed to improve the skills of the next generation of Australia’s fisheries scientists, such as the ‘Advanced Stock Assessment Workshop’ run by Carl Walters and Ray Hilborn at Queenscliff in 1986. He and Rosa were also heavily involved in community work in the Cronulla-Sutherland area of southern Sydney, raising funds for the rehabilitation unit at Sutherland Hospital, and volunteering at the Cronulla community arts theatre.

K Radway Allen’s extraordinary career in fisheries science spanned 70 years. He studied insect, fish and mammal populations in four countries, and rose to be the Director of the premier fisheries research laboratory in three of those countries. He authored more than 100 scientific manuscripts and books, and had the unique distinction of having two papers published in the same journal 50 years apart! He was deeply involved in the scientific community, and was an active member of nine professional societies - including being a gold member of the American Fisheries Society and an honorary life member of the New Zealand Ecological Society, the Australian Marine Sciences Society, and the Australian Society for Fish Biology. This last Society in 1995 named its most prestigious award in K’s honour - the award is given at the discretion of the President of the Society for “an outstanding contribution in fish or fisheries science” - and all agree that such an award epitomises the life and research of K Radway Allen.

There were many tributes after K passed away in February 2008, and in addition to his outstanding contribution to fisheries science all remarked on his generosity of spirit, his willingness to advise and counsel younger scientists, and his extremely calm and deliberative approach to science. This legacy is sure to live on in those whose careers and lives have been influenced by this remarkable gentleman.

Acknowledgements

The author is indebted to Susan Barrett who compiled much of the background information on K's early history and provided the photos used in this paper.

Photographs from the Archive

K Radway Allen as a young scientist, with sampling gear (c. 1940)

K Radway Allen with his wife Rosa (c. 1942)

K Radway Allen - Director, Fisheries Research Board of Canada (c. 1967)

K Radway Allen with IBM 1130 Computing System, Nanaimo, Canada (late 1960s)

K Radway Allen (far left) at International Whaling Commission meeting in London in 1978 with (from left) John Bannister and Arthur Bollen (Australia), Thordur Asgeirsson (Iceland), Ray Gambell (UK) and Bill Aron (USA).

K Radway Allen with John Gulland (c. 1970s?).

K Radway Allen (centre left, in shadow) with participants at Australian "Advanced Stock Assessment Workshop" run by Carl Walters and Ray Hilborn, Queenscliff, Victoria, May 1986.

K and Rosa Allen aboard a CSIRO research vessel during sea trials.

K Allen Presentation:
The metamorphosis of larval-fish biology in Australia: from who to where to what

Jeff Leis

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Jeff Leis is a Principal Research Scientist in Ichthyology at the Australian Museum in Sydney. He has been fascinated by and studied fish larvae in the warmer waters of the Indo-Pacific for 37 years. Jeff did his BSc in Zoology at the University of Arizona, where he got his ichthyological start in the Gulf of California, and his PhD in Biological Oceanography at the University of Hawaii, where he fell in love with coral reefs and their fishes. After 18 months in southern California, studying the impact of nuclear power stations on fish larvae, he departed the USA for a 2-year fellowship in Australia, and became a new Australian. Jeff's research on fish larvae has provided a taxonomic base for their study in the Indo-Pacific, used them to reveal the relationships of fishes, and shown their behaviour can strongly influence dispersal in the ocean. He has been privileged to participate in the Australian Museum's golden age, to collaborate with a wide variety of stimulating people, and to do field work in the most interesting places. Jeff's research has helped to shine some light into the black box of larval-fish biology, and he has enjoyed every minute of it.

Most teleost fishes have larval stages that differ in appearance, habitat and most aspects of biology from the adult, and this has profound implications for fish biology, our study of it and attempts to manage fishes. These differences have defined the main research thrusts in the early life history of fishes in Australia: who are the larvae, where are they, and what are they doing? Overseas larval-fish research has traditionally focused on schooling commercial species, particularly on the Orders Clupeiformes, Gadiformes and Pleuronectiformes with an emphasis on stock assessment, and has been largely conducted by fisheries organizations. In Australia, the research has been more ecological in nature, with a greater focus on Perciformes, stock assessment has played a relatively minor role, and the much of the larval-fish research is conducted by non-fishery workers.

Prior to the 1970s the very little Australian research on fish larvae was primarily taxonomic, and there were no larval-fish specialists. From the 1980s, although few people were actually employed to do larval-fish research in Australia, larval-fish specialists appeared with an emphasis on the taxonomic question of "Who?", and larval-fish identification guides - both Australian and overseas – began to provide a sound taxonomic underpinning for larval-fish research, and also the basis for sorting out relationships in a number of groups: this continues today. Initially, research on the ecology of fish larvae was primarily distributional and based on towing fine-mesh nets, and often involved sampling over rather large scales with large ships. This approach asks "Where?", and provides valuable quantitative information on where larvae

are during the pelagic phase, and what habitats are required: this continues, albeit with much more sophisticated nets.

From the 1990s, less conventional sampling methods (eg, seines, light traps, crest nets) began to target the settlement-stages that largely elude towed nets, and shifted the focus from the early portions of the pelagic stage to its survivors, and heralded a shift toward asking "What?". This took place in concert with a realization that the larval otolith can inform us about many events during the pelagic stage. Throughout, a primary concern has been dispersal of larval stages, a combination of "What and Where?". This has taken on more importance with the increasing emphasis on Marine Protected Areas and has led to work on the how behaviour of fish larvae might influence dispersal outcomes: a "What" question that has been done primarily in Australia. We can look forward to more Australian work on these who, where and what questions about fish early life history using a blend of traditional and innovative approaches.

Student Travel Award:
A generalized trophic approach to stocking density and predatory impact estimation for stocking in open systems

Matt Taylor

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Matt Taylor is an Australian Research Council Postdoctoral Fellow at the University of New South Wales. Matt graduated with his PhD in March 2007, and since then he has established a research group developing stock enhancement for marine systems in New South Wales, including four PhD students. Matt's work draws on ecological and genetic principles in the development of responsible approaches to stock enhancement, using mulloway *Argyrosomus japonicus* and eastern king prawn *Penaeus plebejus* as model species. He is a current AIPS Young Tall Poppy, and he maintains active research collaborations with The Oceanic Institute, Hawaii, Mote Marine Laboratories, Florida, and The Imperial College, London.

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Rigorous assessment of species and ecosystem biology underpins responsible marine stock enhancement. Estimation of appropriate stocking density based on ecosystem productivity and energetic requirements of stocked species can refine the magnitude of release densities

used in pilot-scale enhancement experiments, minimizing waste of resources and the possibility for adverse stocking effects. A generalised mass-balance model for stocking density estimation is proposed. The approach is loosely based on the principles of ECOPATH, and modified for the dynamic estimation of stocking-related ecosystem relationships at fine temporal (days) and spatial scales. Main parameter inputs include basic biological and life history data for stocked species, and estimates of primary productivity for the target ecosystem. The energetic requirements of stocked fish are evaluated in terms of growth and mortality, and ontogenetic transitions in diet, habitat use, morphology and migration. The theoretical carrying capacity for a stocked species within a given arena is assessed from trophic models and levels of predation on different prey groups. Stocking density is estimated through evaluation of energetic requirements against productive capacity of the spatial habitat range for stocked fish, and length-based mortality functions. Potential harvest and predatory impacts, and various indices for comparison of stocking scenarios are estimated. The model is applied for stocking early stages for a range of species of varied biology and geographic areas, including omilu (*Caranx melampygus*) and Pacific threadfin (*Polydactlus sexfilis*) in Hawai`i USA, snook (*Centropomus undecimalis*) and red drum (*Scianops ocellata*) in the Gulf of Mexico USA, and mulloway (*Argyrosomus japonicus*) in Australia. The potential for the approach in appraising stocking scenarios is demonstrated, along with key limitations of the approach and ideas for further development.

RECREATIONAL FISHERIES

Thirty years down the line: Changes in the recreational fishery in the Blackwood estuary, south-western Australia

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Although anecdotal evidence about changes in recreational fishing quality abounds, quantitative historical data on recreational fisheries in Western Australia is unusual. In this study, fishing effort, catch and catch rates by recreational anglers in the Blackwood Estuary in 2005-06 were determined using a roving creel survey and contrasted with unique, published data collected in this system by the same method during 1974-75. Patterns in seasonality of effort and catches recorded in the two surveys were similar with the summer and autumn months favoured by local and tourist anglers alike. *Sillago schomburgkii* and *Arripis georgianus* still dominated the catch but the highly targeted, endemic, estuarine-resident species *Acanthopagrus butcheri* had declined considerably in the catch. Surprisingly, total effort in 2005-06 was similar to that expended in 1974-75 but there was a marked shift towards shore-based angling concentrated at easily accessible locations in the lower reaches of the estuary. Overall, from the information on time spent fishing prior to each interview, duration of fishing trips appears to have reduced considerably over the 30 year period. Both boat-based and shore-based catch rates had also declined markedly with the overall catch rate only 0.835 fish per angler per hour compared to the earlier 4.170 fish/ angler/ h. Total estimated catch was only 20% of that estimated for 1974-75. Although size distribution data were not collected in 1974-75, the recent data indicate that, despite an apparent high release rate of small or undesirable fishes, compliance with minimum legal length regulations was poor for several species. The influence of the imposition of recent bag limits was explored by applying the 2005 limits to the recorded catches of each angling party in 1974-75 and, although catches of *A. berda* would have been less, there was negligible effect on overall catch rates. High resolution temporal and spatial data on distribution of fishing effort in terms of numbers of anglers is presented and the total number of anglers fishing in the Blackwood Estuary in 2005-06 was also calculated.

Where have all the fishers gone?: declining participation trends in recreational fishing in Queensland

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Between 1996 and 2004, participation in recreational fishing in Queensland, Australia declined from 28.1% to 20.6%, and the number of active recreational fishers declined from 882,200 to 733,400. These statistics indicate that people are being displaced from recreational fishing and are not being replaced with new recruits to the activity.

In 2005, a survey of Queensland residents who reported ceasing participation in recreational fishing was undertaken to understand constraints on fishing participation, reasons for discontinuation of fishing, and factors that would influence former fishers to resume participation. The most commonly cited reasons for ceasing participation were lack of time (34%), loss of interest (21%), poor fishing quality (17%), lack of access to fishing areas (13%), and lack of fishing partners (11%).

Results suggest that ceasing fishing had little effect on overall level of recreation participation and overall recreation satisfaction for most respondents. About 50% of respondents reported a desire to fish more often; however, most did not believe it likely that they would participate in fishing in the following 12 months.

The most commonly cited factors that would encourage individuals to resume fishing participation were more time (18%), finding someone to fish with (12%), and improved fishing quality (11%).

NSW gamefish tournament monitoring – past, present and future

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The club-based gamefishing fraternity are relatively organised as a recreational fishery. Their organisational structure involves the recording of both catch and effort information through their mandatory radio schedule reporting system (*Scheds*). Using this system as a basis for data collection, scientific monitoring of gamefish tournaments was initiated in 1993/94. This was considered to be a cost-effective method to collect long-term and spatial catch and effort information for this fishery. It was recognised, however, that *Scheds* can not provide complete information on targeting practices or the catch of species which are not associated with competition points (such as fish that are either kept for food or used as bait). An on-site post-

fishing interview component was therefore incorporated into the monitoring regime. This project is also shifting from relatively haphazard observations to more structured sampling and analysis that utilises probability-based survey methods. Even so, numerous assumptions are still made when estimating total catch and effort and their associated precision. These assumptions are discussed and possible methods to address them are presented. Patterns in the data, such as catch rates over time, are also shown for some of the following primary gamefish species: the three marlin species, blue (*Makaira mazara*), black (*Makaira indica*) and striped (*Tetrapturus audax*); shark species, shortfin mako (*Isurus oxyrinchus*), tiger (*Galeocerda cuvier*) and blue (*Prionace glauca*); and, tuna and sportfish species such as yellowfin tuna (*Thunnus albacares*) and mahi mahi (*Corpheana hippurus*).

The WA recreational logbook program – evaluation of progress after three years

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A daily logbook for recreational fishers was implemented in WA in mid-2005. Since then fisher participation rates and spatial coverage have gradually increased. The logbook is now being used by shore- and boat-based fishers in most regions of the state. A large proportion of logbook data currently being generated relates to the West Coast and Gascoyne regions. These regions are currently a focus for fisheries managers in WA, with the implementation of Integrated Fisheries Management (IFM).

I will present examples of logbook data (catch rates, length composition of retained and discarded catches, distribution of catch/effort) for various key recreational species in these regions, including IFM indicator species. Comparisons will be made with data from other types of recreational fishing surveys. Potential applications and limitations of logbook data will be discussed

A boom and bust recreational scallop fishery

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Overfishing has collapsed the southeast Tasmanian D'Entrecasteaux channel scallop fishery several times in the past 100 years. In 1990 the fishery was restricted to recreational dive fishers only and long temporal closures introduced to allow stocks to replenish. However the management strategy over this period of boom and bust cycles proved to be ineffective. In 2005 after a decade of closure, the scallop fishery again re-opened as a recreational dive fishery with radical changes to management including; very low bag limits, larger size limits and an extended season to the remove the "gold rush" mentality previously associated with

the fishery. The question is now whether these management measures are sufficiently conservative to preserve this iconic and hugely popular recreational fishery. Importantly, the biology and spatial dynamics of the species are extremely complex and there are new pressures on the scallop stocks such as the rapid expansion of the introduced Northern Pacific Seastar population. This study uses cost effective surveys of licensed fishers and dive surveys in collaboration with recreational dive clubs to generate performance indicators and suggests that static management may not be as effective as thought and another bust cycle may be looming around the corner.

The Western Australian charter boat industry: working towards long-term sustainability

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The Tour Operators and Aquatic Eco-Tourism (Charter) sector forms a vital part of the Western Australia fishing community and have been proving statutory catch and effort returns since 2002. This study will provide a detailed evaluation of the Western Australia charter sector to assist in the long-term sustainability of the sector and the natural resources they depend on. This will be achieved by understanding the dynamics of the charter sector, firstly, through an examination of spatial and temporal trends in effort and catches of target and non-target species. Secondly, the study will compare the temporal and spatial trends in the catch, effort and size composition of pink snapper (Pagrus auratus), an important species to most of the sector. The relative impacts of the charter, recreational and commercial sectors on pink snapper stocks will be assessed. Finally, the study will examine aspects of the social and economic trends to assist with developing strategies for the long-term management of this sector. Preliminary results of this project will be presented.

Recreational fishers' attitudes towards the 2004 rezoning of the Great Barrier Reef Marine Park

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Recreational fishing is a popular use of the Great Barrier Reef Marine Park. In 2004, the Great Barrier Reef Marine Park Authority implemented a new zoning plan for the Great Barrier Reef (GBR) that increased no-take areas from 5% to 33% of the total park area. Anecdotal evidence before and after the rezoning suggested that the recreational fishing community was not supportive of the rezoning plan. A survey of 800 GBR recreational fishers conducted in 2007, however, revealed strong support for the rezoning plan among recreational fishers. Most fishers surveyed also believed that the rezoning plan was necessary and would have positive impacts on conservation of the GBR and the sustainability of its fisheries. However, many

recreational fishers expressed dissatisfaction with the rezoning and consultation processes. Results demonstrate that recreational fishers consider the conservation value and necessity of the plan, the adequacy of the consultation process, and the impacts of the plan on their fishing activity when forming attitudes (i.e., support or opposition) regarding the plan.

Ongoing research and management for the long term sustainability of the west coast demersal scalefish recreational fishery, Western Australia

Brent Wise and Nathan Harrison

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Assessments of key indicator species in the West Coast Demersal Scalefish Fishery highlighted the need for major management changes in the commercial and recreational (including charter) sectors. Community discussion of proposed management measures and ongoing research for each sector has occurred and are being implemented into the ongoing management of the fishery.

The boat-based recreational fishing forms an important component of the West Coast Demersal Scale Fishery requiring cost effective research and management measures to reduce and control the catch and effort of demersal species. These include ongoing monitoring of changes in fishing practices resulting from the new management regime, the ongoing estimation of boat-based recreational catch and effort and collection of biological samples to update assessments.

An update on the proposed and implemented management measures and research monitoring and assessment programmes for the west coast demersal scalefish recreational fishery will be presented.

Developments in using aerial fishing effort surveys to scale up observed harvests

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Recreational fisheries often extend along extensive areas of coastline and are accessed by numerous and scattered access points. Because of the scale and complexity of these fisheries, researchers often use indirect approaches to assess recreational harvests and effort such as telephone diary surveys, where catch data provided by a subset of fishers is taken at face value, with limited corroboration. Indirect harvest estimation methods are no longer favoured in New Zealand, following a critical examination of several national surveys which concluded that available estimates were of dubious and indeterminable reliability. A shift towards more

direct and fishery independent methods has led to the development of a novel and cost effective method, which has been used successfully to assess recreational harvests from New Zealand's largest inshore fisheries.

The method uses a single flight per day to determine the number of parties fishing from vessels at a fixed point in time. Creel surveys are also conducted concurrently to determine both the day's harvest landed at surveyed ramps, and the number of parties fishing at the time of the overflight. The ratio of the number of parties observed from the air relative to the number of interviewed parties who reported fishing at the time of the overflight is used to scale up the observed subsample of the fisheries catch on a day. The method is, therefore, a cost effective adaptation of the conventional Aerial-Access approach, but only requires a single flight per day, and is not reliant on any catch rate estimates. Recent surveys suggest that this approach can provide plausible harvest estimates which are widely accepted.

Trends in Queensland's recreational fishing catch, harvest and release

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In response to the growing awareness of including recreational catch estimates into the fisheries management planning process, the Queensland government initiated a state wide longitudinal sampling program to collect information relating to recreational fisheries. The information was collected as part of the Recreational Fisheries Information System (RFISH) program which was developed in 1995 to provide managers, policy makers, industry and researchers with catch estimates for the Queensland recreational fishery to enhance the management of Queensland's fisheries resources.

To calculate the catch estimates, fishing participation rates collected using a random telephone survey of the Queensland population were combined with catch estimates volunteer fishers provided through a 12 month diary program. The diary participants were identified during the random telephone survey and provided information on where they fished, what they caught and released how long they spent fishing and their method of fishing. Approximately 5000 anglers participated in each of the diary programs to provide information relating to their fishing activities.

As there have been four estimates of state wide catch data, this presentation takes the opportunity to look at trends in catch, harvest and release between 1997 and 2005 and identifies changes in catch reflected by the introduction of management plans, in particular

the Fisheries (Coral Reef Fin Fish) Management Plan 2003. As a result of a significant decline in participation over the four surveys, this presentation also looks at catch rates on various species of interest across the four diary surveys.

Gone fishing? – Using recreational fish catch data to assess trends in fish stocks in Queensland

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Recreational fish catch data sets from local and regional competitions held by fishing clubs are largely unexplored. Recreational fish catch data are available for some regions but are generally based on return of survey forms provided by various fishing clubs on a voluntary basis. However, most fishing clubs keep their own records of fish species catch and weight. Such records often represent the only long-term data for a particular estuary or region. We have used a nine-year data set of recreational fish catch data from the Burrum River, Queensland to detect trends of overfishing and species assemblages. Analyses of the data set showed downward trends in weight per fish per year for four dominant species and a trend from brackish water species to marine species over the period of nine years. For example, whiting (*Sillago* spp.) experienced a significant decline in weight and total catch in the estuary system, which is supported by anecdotal reports from local commercial fisher who claim a reduction of catch with increased efforts. Recreational fish catch data can provide information on regional trends and allow comparison over various temporal and spatial scales. Such information is important for improving current commercial catch data and for better stock management.

Do club-based anglers have a disproportionately large influence on estimates of total fishing catch and effort estimates in a recreational fishery?

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Fisheries agencies throughout Australia often engage with recreational fishing clubs to collect data for management and research programs. Historical trends in club-based catch rates have been used previously as indices of relative abundance through time. Many other types of club-based data are also collected routinely by many different fisheries agencies, such as, tag and release data, tournament catch and effort data, diary records of catch and effort for avid fishers, and socio-economic information.

Cooperative monitoring programs are useful for building links between fisheries agencies and recreational club-based fishers and they provide an opportunity to collect large quantities of

data on recreational fisheries in a cost-effective way. However, it is usually assumed that analysis of these club-based data will provide insights that are also applicable to the general fishing population and hence provide reliable indicators of fishery status. That is, it is assumed that these club-based data are representative of the larger recreational fishing population. We ask three questions:

1. Do club-based anglers have a disproportionately large influence on estimates of total fishing catch and effort estimates in a recreational fishery?

2. What implications does this have when interpreting club-based data?

3. What implications does this have when designing representative surveys for the assessment of recreational fisheries?

We used data from the NSW module of the National Recreational and Indigenous Fishing Survey (NRIFS 2000-01) to answer these questions. The NRIFS was conducted over a 12-month period from March 2000 to April 2001. The primary data sources for the NRIFS were a general population screening survey and a diary survey. The screening survey provided estimates of the level of participation in recreational fishing, and recruited fishers to participate in a diary survey. Fishing effort and catch data were then collected over a 12-month period using the diary survey.

Monitoring recreational catch in remote Queensland – a change in tactics

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The Gulf of Carpentaria, Queensland, includes some of the most prime recreational fishing locations in Australia, attracting tens of thousands of recreational fishers each year. Information from recreational fishers in the Gulf of Carpentaria is required to ensure the sustainability its fisheries.

DPI&F monitor Spanish mackerel and barramundi catch in the GoC as part of its ongoing monitoring program. DPI&F has used a range of sampling strategies to collect length, age and sex data representative of retained catches from multi-sector fisheries on the east coast. These strategies have proven effective in highly populated areas such as southeast Queensland. We are now adapting these strategies to increase their effectiveness in remote areas of Queensland, in particular the Gulf of Carpentaria. In doing so, we have encountered several difficulties unique to sampling in remote locations. This presentation will outline the difficulties we have faced when sampling recreational catch in remote areas of the GoC and discuss how we've adapted our strategies to monitor these remote fisheries.

EARLY LIFE HISTORY AND OCEANOGRAPHY

Unique replicates or like chalk 'n cheese? The Leeuwin versus the East Australian Current

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Australia is uniquely bracketed by poleward flowing currents, the Leeuwin and the EAC. The research on both currents is briefly summarized. The Leeuwin is a winter current, averaging ~5 Sv annually, stimulating winter production and upwelling and pilchard spawning. Associated with the Leeuwin is the Capes Current and the Ningaloo. The Leeuwin has a strong annual ENSO signal indicated by the sea level heights (stronger in la Nina), providing useful correlations of Fremantle sea level with fisheries recruitment in a variety of species. The EAC is suggested to be a summer current with a core 100 m deep, 100 km wide, travelling at up to 2.5 m s-1, ~30 Sv annually. The region is characterized by spring-summer production & upwelling at two locations off northern NSW, along with local wind induced effects. It has more eutrophic waters and may be less affected by nutrient discharge. There are local counter currents between the headlands that are likely vital for connectivity and larval retention. There is no ENSO signal along NSW and the EAC flow is characterized by "Intrinsic instabilities" in the headwaters of the Coral Sea. Nevertheless there are similarities in the processes that form coastal anticyclonic (Leeuwin) versus cyclonic (EAC) eddies. Recent plans by the Integrated Marine Observing System (IMOS) to compare these currents, and the conceptual advance of such a comparison will be discussed.

The horizontal and vertical distribution of fish eggs and larvae in Western Port and on the adjacent Bass Strait coast, September 2007 to June 2008

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Fish eggs and larvae were sampled monthly from September 2007 to June 2008, to assess the horizontal and vertical distribution of fish eggs and larvae in relation to the proposed desalination plant for Victoria. Sampling was conducted at 0.5m under the surface and 1-2m above the bottom at 1, 2 and 5 km from shore along transects off Kilcunda and Wonthaggi.

Fish larvae were dominated by threefins, clingfish, gobies and blennies. A number of important recreational and commercial fishing taxa were also collected including, King George whiting (Sillaginidae), garfish (Hemiramphidae), dory (Zeidae), trevally (Carangidae) and snapper (Sparidae). Larvae of reef fish taxa that would occur in marine protected areas such as wrasse,

scalyfins and leatherjackets were also collected. Larvae of taxa of conservation value such as pipefish (Stigmatopora) and seahorses (Hippocampus) were collected. The most abundant larvae of forage taxa were anchovy (Engraulidae).

Abundances of anchovy eggs were highest in September and declined over the following months. No significant difference in concentrations of eggs was found between surface and bottom samples. Concentrations of anchovy larvae varied significantly between month No anchovy larvae were recorded in September, however high densities (>33 larvae per 1000m^3) were recorded in October, January, March and May. Differences in anchovy larvae concentrations were significant between surface and bottom samples. The highest concentrations of anchovy larvae were recorded from bottom samples.

Is the abundance of amphidromous fish determined by juvenile production?

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In amphidromous fish, a short juvenile phase in a pelagic (usually marine) habitat is followed by a longer adult phase in freshwater. Management has traditionally focussed on adult habitat, but little is known of the relationship between juvenile production and recruitment, and adult abundance. We examined the relationship between juvenile rearing habitat and adult abundance in coastal fiord systems in Fiordland, New Zealand. We hypothesised that higher abundances of adult fish, sustained by strong juvenile recruitment, would be observed in:

(i) streams that drained into the inner reaches of fiords where exchange with the marine environment is limited and the retention of larval fish and their pelagic prey is potentially high.

(ii) fiords that are, on average, relatively more productive.

We sampled multiple streams for amphidromous fish flowing into either the inner or outer reaches of seven fiords. The fish community was dominated by koaro (*Galaxias brevipinnis*) and redfin bully (*Gobiomorphus huttoni*). Both species were approximately five times more abundant in inner fiord streams relative to outer fiord streams. For both species, population size structure was skewed by high numbers of juvenile fish in inner fiord streams indicating strong recruitment. Fish age/size classes were more evenly distributed in outer fiord streams. Streams draining into the most productive and retentive fiords also supported the highest densities of fish. The results suggest that the abundance of amphidromous fish in coastal streams is influenced by variation in juvenile recruitment that in turn is related to coastal morphology and productivity.

Pulsed environmental events and temporal variability in otolith chemistry

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Otolith chemistry is frequently employed as a natural tagging technique that relies on spatial variation in various elements and isotopes. However, temporal variability in some chemical markers can be substantial in response to fluctuations in ecologically important parameters such as temperature, salinity, and nutrient availability. Thus temporal variability in geochemical signatures can potentially reveal important information about the frequency and intensity of pulsed environmental events and their ecological effects. We present results from an on-going effort to monitor water chemistry and associated variability in Ba:Ca recorded in otoliths of a resident pomacentrid as well as coral carbonate at two locations in the Great Barrier Reef. At an outer reef site in the Great Barrier Reef (Myrimodon Reef) fluctuations in ambient and carbonate Ba:Ca ratios correlated with upwelling events. In addition, the effects of upwelling varied at fine spatial scales both within a reef and with depth. At inshore reefs (Pandora and Havannah Reefs), Ba:Ca ratios responded to freshwater inputs and flood events, thereby acting as an effective proxy for anthropogenic influences on nearshore habitats. Coupled with estimates of growth rate responses at different life history stages, temporal variability in otolith Ba:Ca has the potential to reveal ecological responses of fish populations to high-frequency fluctuations in oceanographic parameters.

Do spawning patterns affect recruitment of snapper (*Pagrus auratus*) in northern Spencer Gulf?

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The biomass of snapper in SA shows considerable inter-annual variation resulting from changes in 0+ recruitment. To understand inter-annual recruitment variation, temporal patterns of reproduction were studied in Spencer Gulf, the region that contributes much of South Australia's snapper catch. The timing and frequency of spawning were used to formulate hypotheses on patterns of 0+ recruitment and compared to measured patterns of successful spawning of 0+ snapper.

Reproductive samples from northern Spencer Gulf collected during 2005/06, 2006/07 and 2007/08 were analysed macro- and microscopically. Spawning activity was determined by calculating spawning fraction estimates and batch fecundities. The effect of fish size on each of these parameters was also considered. The pattern of successful spawning was determined using frequency distributions of back-calculated spawn dates estimated from the sagittae of 0+ snapper collected in annual trawl surveys.

The onset of spawning varied between years but occurred when water temperatures were between 19 and 20ºC. The length of the spawning season differed between years but peak spawning activity occurred during December, when fish spawned almost every day. Spawning frequency and relative batch size did not differ between the first two spawning seasons but during the 2007/08 season batch size was considerably greater and spawning fraction reduced. Thus, successful spawning was likely to have occurred in December, but was probably more sporadic in 2007/08 than the previous two seasons. Back-calculated spawn dates provide evidence that these changes in spawning activity, whilst important, are not always the primary determinant of successful recruitment.

FISH BIOLOGY

Comparative biology of four species of emperor (Family Lethrinidae) on the Great Barrier Reef

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Little is known about the life-histories of many species included in the “other species” Total Allowable Commercial Catch (TACC) quota group in the Great Barrier Reef Coral Reef Finfish Fishery (CRFF). Species of the family Lethrinidae (Emperors), which are regarded as protogynous hermaphrodites, comprise a substantial proportion of this catch. Understanding the species-specific biology of fish is important for appropriate management of multi-species fisheries, as variation in life history may indicate different vulnerability to fishing pressure. We investigated size, age, growth, mortality and reproduction for four species of lethrinids commonly encountered in the CRFF, with samples collected from fishery independent surveys. Like other coral reef fish families, life-history characteristics varied among these species. In particular, two distinct groups were identified: the more elongate species (*Lethrinus nebulosus* and *L. olivaceus*) which appear to have relatively short life spans and continual growth throughout life; and the small, rotund species (*L. atkinsoni* and *L. lentjan*) which have a greater longevity and show fast initial growth which reaches an asymptote relatively early in life. Further differences among species were observed in reproductive biology. The peak spawning period differed among species and substantial variation was identified in the developmental pathway of males, which indicates significant plasticity among species with regards to protogynous hermaphroditism. This variation in life-histories may mean species are affected differently by anthropogenic influences such as fishing, as slow growing species with long life spans may be more vulnerable. Thus, species-specific regulations are also important to protect species within the “other species” quota group.

Lek-like behavior of a Parrotfish, *Chlorurus sordidus* (Scaridae), on a resident spawning aggregation site at Guam, Mariana Islands

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Reef fish spawning aggregations demonstrate predictable spatial and temporal patterns in form and function. However, the scale of migration to spawning aggregation sites and the formation are highly variable among reef species. Fishes may form transient or resident spawning aggregations. Transient aggregations involve migrations by participants of up to hundreds of kilometers during a limited time period. Resident aggregations typically involve migrations of individuals from home ranges or feeding grounds to an adjacent location, and may occur on a daily basis. Parrotfishes (Scaridae) are among the more dominant inhabitants of coral reefs and sea grass beds and play an important role in subsistence and commercial fisheries. These fishes form resident spawning aggregations and display behavioral characteristics resembling those of lek-like mating systems. Leks are temporary aggregations of sexually active males that form for the purpose of reproduction. Leks and lek-like behavior offer a good system for better understanding direct and indirect mate choice. In this study, I describe the mating system of *Chlorurus sordidus*, a common species of parrotfish, on a resident spawning aggregation site in Guam. I observed male-male interactions and male-female spawning during mid-late morning (0900-1200H). This species forms a lek-like mating system characterized by male-male social interactions that appear to establish dominance and delineate temporary territories, courtship of females by repeated displays before spawning attempts, and minimal feeding by males during courtship periods. The data indicate that females may be choosing males indirectly based upon location of their temporary territories resulting in males competing for each site.

The relative contribution of environmental and maternal factors in phenotypic variation in fish populations

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Maternal effects may be a key source of phenotypic variation in offspring traits but are likely to explain only a small portion of total phenotypic variance in nature. The recent focus on maternal effects as a driver of the variation of early life-history traits and recruitment is at some risk of undervaluing other sources of variation such as the offspring's environment. The estimated magnitude of maternal effects on phenotypic variance in offspring traits will depend on the environment experienced by the offspring. We evaluated the reported magnitudes and pattern of occurrences of maternal effects and environmental interactions in an attempt to identify basic expectations when two or more sources of variation are operating concurrently. Here we summarize that review and compare the magnitudes of maternal effects versus other

environmental factors on phenotypic variance. We then use species with contrasting reproductive and early life-history traits in examples of the possible interactions between maternal effects and environmental factors. Lastly, we identify the current gaps in our information about the occurrence and combined role of maternal effects and environment in recruitment variation.

FRESHWATER FISH

Sustainable Rivers Audit: a river health check for the Murray-Darling Basin

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The Sustainable Rivers Audit (SRA) is an initiative of the Murray–Darling Basin Commission partnership.

The SRA has completed its first basin-wide assessment of river condition for the Murray–Darling Basin, based on hydrology, fish and macroinvertebrate themes for 2004–2007. Along with the CSIRO Sustainable Yields project, the river condition assessments will provide critical information to address water resource over-allocation.

Data from the 487 fish sites, 773 macroinvertebrate sites and 469 hydrology sites has been collated, aggregated and reported through indicators and descriptive statistics of interest to managers, researchers, policy makers and other communities.

The 23 SRA valleys within the basin have been ranked in terms of overall ecosystem health by the Independent Sustainable Rivers Audit Group, with one valley (Paroo) in good condition, two in moderate condition and 20 in poor or very poor condition. When ranked by river health the Darling, Central Murray and Lower Murray valleys were toward the middle indicating that impacts are not simplistically cumulative from headwaters to the mouth of the Murray.

This presentation will provide a summary of the design, the implementation, the outputs for each theme and the overall ecosystem health scores.

When good wetlands turn bad - the plight of the Murray hardyhead (*Craterocephalus fluviatilis*) in two lakes in North-West Victoria

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Murray hardyhead are a threatened native fish species currently limited to four Victorian and two South Australian populations. At least three isolated populations have become extinct in recent years, with the ongoing survival of another three uncertain. This presentation describes the findings of four years of monitoring the population dynamics of the species in Cardross Basin 1 and Lake Hawthorn near Mildura. Both wetlands are managed for irrigation disposal and are experiencing declining water levels and increasing salinity as a result of improved drainage practices. Delivery of environmental water to the lakes over the past two years has

been problematic, culminating in watering of only a fraction of Cardross Basin 1 with no environmental water delivered to Lake Hawthorn.

Murray hardyhead continue to survive in highly sulfidic conditions and salinities up to 71,000µS.cm^{-1} in Lake Hawthorn. Due to habitat loss (total death of aquatic vegetation.) in Cardross Basin 1 West all fish species have disappeared. The smaller Cardross Basin 1 East which received environmental water continues to support Murray hardyhead and several other fish species. This talk discusses how similar threats to each population have impacted differently in each system.

Distribution and habitat preferences of freshwater catfish *Tandanus tandanus* within Washpen Creek

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Washpen Creek is a 12km long section of the Euston Lakes system situated within the Murray River lock 15 weirpool. In 2007 a regulator was constructed on Taila creek to disconnect the system from the Murray River for drought contingency water saving measures.

Following the detection of a freshwater catfish population in Washpen Creek, environmental water was pumped during summer to maintain water levels for their conservation. The aim of this study was to determine the distribution and habitat preferences of catfish within Washpen Creek. Habitat surveys showed Washpen Creek comprises two distinctive habitat types. Habitat type (1) is deep channel and habitat type (2) is shallow channel. Both types are fringed with *Typha, Vallisneria spp.,* and *Potamogeton spp.,* and are heavily snagged with coarse woody debris. Habitat type (2) has beds of submerged *Potamogeton* and *Vallisneria spp.,* which often spread across the width of the channel.

Fish surveys using standard techniques have demonstrated that sites within the deep channel contain higher abundances of catfish than sites within the shallow channel. The distribution of catfish among the two habitat types is discussed in relation to physical habitat and water quality.

Investigating the distribution and abundance of fish assemblages in the Moonie River, upper Murray-Darling Basin, using *Macquaria ambigua* as an indicator species

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For Australian dryland rivers, our current understanding of the natural cycles of 'boom and bust' and the response by biota to these fluctuating conditions is limited to a handful of studies in only a few catchments. It is unknown whether the fish present in isolated waterholes during bust conditions are simply random associations of species, or whether a combination of environmental factors is responsible for determining the distribution and abundance of waterhole fish assemblages.

This presentation draws on aspects of my honours project, which aimed to investigate the influence of hydrological, floodplain, geomorphological, riparian and trophic mechanisms on the distribution and abundance of fish assemblages in the Moonie River over a 25 month sampling period. The main focus of the project was, however, on yellowbelly (*Macquaria ambigua*) associations with habitat and food resources. As an ecological generalist placed at the highest trophic position in the Moonie River, yellowbelly was used as an indicator species to answer more specific questions about potential drivers of fish distribution and abundance in dryland rivers.

In general, fish assemblages in the Moonie river could be grouped into two categories based on hydrology: 1) those that followed high flow periods and/or flows following prolonged dry conditions; and 2) and those that followed prolonged periods of zero flow, and/or flows that coincided with cooler seasonal temperatures. The abundance and distribution of *M. ambigua* showed strong associations with floodplain width, riparian condition and waterhole productivity, suggesting non-random interactions between this species and the dryland environment.

Rediscovery of the southern purple-spotted gudgeon from the lower River Murray

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The southern purple-spotted gudgeon *Mogurnda adspersa* (Castelnau) is an attractive small fish (<150mm) being one of the first species to ignite early naturalists and aquarists in Australia. It is among the many freshwater fishes to have undergone dramatic decline in the now heavily modified Murray-Darling Basin (MDB). The species has been presumed extinct in South Australia since the early 1970s and apart from one fleeting glimpse at an isolated lake system in Victoria, was also assumed lost from the wider southern MDB. Small pockets do occur well removed in northern tributaries to the Darling River.

This paper reports on the rediscovery of *M. adspersa* from the highly altered Lower River Murray at a major outlier site near the terminus of the system, some 2500 river kilometres from the nearest known population. The nature and basic ecology of this population is documented from field studies as part of evolving conservation measures in the face of unprecedented environmental change. The combined effects of drought and water abstraction have recently led to the probable extirpation of the wild population soon after its discovery. A combined molecular approach confirmed the 'nativeness' of the population as a distinct MDB sub-population with a moderate level of allele heterogeneity, and this information provides a platform and impetus for captive breeding as a required conservation measure.

Murray cod management model

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An age-size based stochastic population model has been developed to include a range of management concerns such as examining changes to fishing regulations, changes in flow, could water pollution and weir control, population persistence under different fishing pressures, catch and release mortality, stocking and a number of other key issues pertaining to Murray cod. The model uses risk as the comparative measure for different scenarios and provides support for the decision making process particularly when multiple actions may occur.

Comparing two methods of fish euthanasia to inform an animal ethics committee

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Fish research and its compliance with animal ethics committees in Australia has been somewhat inconsistent among the various research institutions. However, in 2004, the release of the 3rd Edition of the *"Australian code of practice for the care and use of animals for scientific purposes"* and the responsibility for compliance led by each individual state has ensured a consistent approach to animal ethics for research across Australia. Furthermore, there is an increasing recognition by scientific journals, such as *Animal Behaviour* and *Journal of Fish Biology* that research must have been done in an ethical manner if it is to be published. Having research methods assessed and accepted by animal ethics committees ensures such ethical standards. As researchers, however, we sometimes have difficulties getting some methods accepted, which varies from committee to committee.

In this presentation we report on one such instance where a committee rejected our initial proposal to use immersion in ice-slurry as a euthanasia method for bony bream, but allowed us to proceed using benzocaine instead. Following negotiations we were allowed to run a pilot study to test the influence of the two methods on levels of fish stress. The results clearly showed that immersion in benzocaine for euthanasia was indeed more stressful to fish than immersion in ice-slurry. Fish in benzocaine exhibited heightened levels of stressful behaviour and took longer to die than fish in ice-slurry. Following this study the ethics committee accepted ice-slurry euthanasia as a standard operating procedure.

Sampling and maintaining genetic diversity in fish rescues: what is the minimum number of fish needed?

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The rescue of imperilled populations from natural or anthropogenic events presents challenges and considerations beyond removal and ex-situ maintenance. One of the main considerations for such programs will be the capture and maintenance of genetic diversity. The capture of allelic diversity will require a sampling strategy that can detect low frequency occurrences in the extant stock. Fish rescue programs that ignore genetic diversity may further increase the probability of extinction when the population is being re-established in the wild. We recognise that rescue operations are done in a time and resource poor environment and in many situations a rescue team may find very few individuals alive when they reach the event site.

The recommendations in this talk are designed with limited resources in mind, while still aiming to meet long-term conservation goals.

Fish length frequency patterns in the rivers of far western Queensland: Evidence of three broad recruitment strategies

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Fish from the Lake Eyre and Bulloo-Bancannia Basins in western Queensland were sampled from September 2006 to April 2008, identified to species and measured (standard length in millimetres). The resulting dataset of over 35 000 individual fish includes records of fourteen native species and two alien species across eight catchments and a variety of hydrological conditions ranging from major flooding to extended periods of no flow. Where sample sizes were large enough, the results for each species were separated into appropriate size classes and analysed using multivariate statistics to investigate the relationship between factors such as flow, season and waterhole type on the resulting length frequency distributions. Results from these analyses suggest that the breeding behaviour of fish species in the hydrologically highly variable watersheds of far western Queensland fall into three main categories, with reproduction occurring in response to either time of year, flooding or independently of these factors and essentially year-round. These results indicate that in un-regulated Australian rivers with variable hydrology, fish employ different strategies in order to effect recruitment success, and that these strategies include, but are not limited to, a reliance on floodplain inundation.

Exotic and translocated native fishes in northern Australia: Current status and future trends

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Northern Australia hosts two-thirds of the Australian freshwater fish fauna and most of the catchments are relatively undeveloped. Few of these undeveloped catchments have exotic or translocated native species. However, the few developed catchments such as in the Wet Tropics region, are heavily affected by such fishes with 20 exotic and 36 translocated native fish species recorded to date in the coastal waterways between Townsville and Cairns alone. Apart from considerable impact in these high value waterways, the spread of exotic species, in particular to the less developed waterways of northern Australia poses a significant and more immediate threat to their biodiversity.

Two species of tilapia – (*Oreochromis mossambicus* and *Tilapia mariae*) – are of most concern. Despite significant public education effort to prevent their further spread, several new

catchments have been invaded in recent years, significantly expanding their distribution. In the Burdekin catchment, 700km of river has been infested in less than 4 years since the first arrival of *O. mossambicus*. This species was also recently confirmed as having established in the Endeavour River, Cooktown. *Tilapia mariae* were recently located in a tributary of the Walsh River. This latest incursion poses possibly the most urgent threat as this river drains into the Mitchell River in the Gulf of Carpentaria. A potential pathway for the spread of exotic fishes from PNG across Torres Strait also exists. This paper discusses the current status of fish pest in northern Australia, current research and management initiatives, and the prognosis for the near future.

Survivorship of invasive, non-native freshwater fish species in relation to habitat disturbance in tropical northern Queensland, Australia

Alan Webb

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Laboratory and field studies were done to test the hypothesis that proliferation of aquatic macrophytes in human-disturbed, nutrient-rich waters creates refugia for hardy, non-native fish species from competition or predation by native fish species. Survivorship of mixed prey populations of two native fish species (Agassiz's glassperch and fly-specked hardyhead) and two non-native species (gambusia and Mozambique tilapia) were recorded in the presence of four native predatory fish species (mouth almighty, barramundi, tarpon and spangled perch) at different levels of vegetation cover (0, medium, dense). The two non-native species had the lowest survivorship in the absence of vegetation cover but the highest in dense cover. These results supported the findings of a field study in the Ross River, Townsville, in tropical northern Queensland, where the highest species richness and abundance values for non-native fishes, where tilapia juveniles and mosquitofish dominated, was in marginal habitats created by dense aquatic vegetation, while the lowest values for these species were found from open waters in the main river channel. Conversely, the highest species richness and abundance of small native fishes was in open waters, while the lowest values were recorded for the marginal non-native 'refuge' habitats. These results are discussed in relation to management of non-native freshwater fishes in Australian waters.

Fish projects in the Fitzroy River, Kimberley, Western Australia - research by the Centre for Fish & Fisheries Research, Murdoch University

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Studies in the Fitzroy River commenced in 2001 and have been ongoing. Strong collaboration between indigenous organisations and communities has resulted in a number of important projects being completed. Projects have resulted in fish posters of the river's fishes in five Aboriginal languages and an increased awareness of the importance of the river to endangered

species, such as Freshwater Sawfish, Dwarf Sawfish, Northern River Sharks, Barnett River Gudgeon and Greenway's Grunter. Species distributions and habitat associations have been completed and the biology of a number of species, including Barramundi, Freshwater Sawfish, Dwarf Sawfish, Bull Sharks and Lesser Salmon Catfish, determined. The diets and trophic relationships for many of the river's fishes have been examined. Genetic work has compared the Fitzroy River populations of Barramundi, Freshwater Sawfish and Dwarf Sawfish to those elsewhere. Tagging (conventional, acoustic and satellite) studies for Freshwater Sawfish are ongoing.

The contribution of terrestrially derived prey to the dry season diet of terapontid grunters in Northern Australia's wet-dry tropics

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There has been considerable recent effort on the part of Australian researchers to establish conceptual frameworks outlining the predicted functioning of many of Australia's rivers, particularly the relative roles of allocthanous versus autochthonous production in aquatic food webs. Results from an array of studies have particularly emphasized the role of autochthonous production in riverine and wetland food webs and apart from reliance on terrestrial invertebrates in a limited array of fish diets, direct trophic linkages to terrestrial zones are considered minimal.

The Terapontidae are the most speciose family of Australian freshwater fishes, with the group reaching its most extensive radiation at both generic and species level in the wet-dry freshwater ecosystems of northern Australia. Although previously collected trophic data suggests minimal overall importance, terapontids are also one of the most frequently mentioned candidates whenever the numerous anecdotal accounts of frugivory that litter the Australasian literature are considered.

This study explored in detail the interspecific and size-related patterns of direct consumption of terrestrially derived resources in the dry-season diets of northern Australian terapontids. Dietary analysis highlighted consumption of significant amounts of an array of terrestrially derived prey items, including riparian fruit, invertebrates and terrestrial vertebrates in the trophic ecology of larger size classes of several terapontid species. These ontogenetic diet shifts appear in part to be linked to the ecomorphological characteristics of particular species. This data provides one of the first quantified examples of a significant role for direct riparian plant subsidies to Australian freshwater fish food webs.

Determining ideal sample size for diet analysis of two freshwater fish

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Analysis of fish diet is necessary to understand the food resources required to support fish populations and detect shifts in diet associated with environmental change. In research studies addressing these issues, the diet of a small number of individuals is often used to assess the needs of an entire fish population. I determined the number of Australian smelt (*Retropinna semoni*) and Cox's gudgeon (*Gobiomorphus coxii*) guts needed to give an accurate estimate of the diet of their populations. Thirty fish of each species were collected in May 2007 from three upland tributaries of the Hunter River, NSW. Diet was assessed using three common diet assessment methods including frequency of occurrence, composition by number and composition by volume. Species accrual curves and differences in the gut contents of increasing numbers of fish were tested using the Bray-Curtis similarity and index of precision statistics to determine the number of guts needed to assess the diet of the four populations. Between 15-25 individuals of both Australian smelt and Cox's gudgeon were considered necessary to accurately determine the diet of the populations. The estimates calculated in this study suggest that previous research of the impacts of environmental change on the diet of fish either use too few individuals, therefore inadequately representing the diet of a population, or too many individuals, therefore over-sampling.

Little fish under threat in a big state: South-Western Western Australia's endemic freshwater fishes

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Widespread habitat alterations and impacts of feral species have led to range reductions and population declines of south-western Australia's highly endemic freshwater fishes. Some species have been lost from systems and/or are restricted to specific habitats within catchments. Habitat alterations primarily due to salinisation, water extraction and river regulation have compromised many populations. Recent studies on distributions, habitat associations, salinity tolerances, migratory patterns and fishway utilisation has greatly increased our understanding of these key threats and has enabled us to identify populations at greatest risk and to begin to predict future viabilities. This research is currently being used to prioritise populations and develop strategies to help ensure their ongoing sustainability.

FRESHWATER FISH – MACQUARIE PERCH

Evolution and maintenance of divergent lineages in an endangered freshwater fish, *Macquaria australasica*

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Genetic diversity is essential for organisms to evolve to changes in their environment. Although geologically relatively stable, southeastern Australia has experienced significant changes in landscape and climate conditions to which species have evolved. For freshwater taxa, variable hydrological regimes and habitat availability have been very strong determinants of current species distribution and population structure. We have conducted a range wide phylogeographical study of Macquarie Perch, *Macquaria australasica*, in order to understand the relationship between landscape and freshwater fish evolution in southeastern Australia, and to assess the levels of genetic diversity and divergence in this endangered species. We found 46 mtDNA control region haplotypes from 35 sampling locations with up to 6% sequence divergence between lineages. Phylogenetic reconstruction indicates that the species originated on the coast, east of the Great Dividing Range (GDR) and subsequently colonised inland to the Murray-Darling Basin (MDB), west of the GDR. Mismatch analysis suggests that this colonisation may have been followed by demographic expansion of the population approximately 536kya. Nested clade and IM analyses also support a series of range expansions and fragmentations across the species range during the Pleistocene. We conclude that the unexpected high levels of diversity and divergence observed in *M. australasica* may be due to the interacting factors of habitat specificity, localised recruitment and Pleistocene climate fluctuations. The comprehensive phylogeographical approach used here has given valuable insight into the aspects of *M. australasicas* biology and its interactions with the environment that may be critical to its conservation management.

Distribution of the threatened Macquarie perch (*Macquaria australasica*) within the Hawkesbury-Nepean catchment, NSW

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The Hawkesbury-Nepean catchment is the largest coastal catchment in NSW. Over 50% is contained within National Park or Sydney Catchment Authority restricted areas, and much consists of very rugged terrain and remains highly inaccessible wilderness. Due to this

inaccessibility, the status of Macquarie perch populations within the entire catchment has previously never been comprehensively assessed.

Macquarie perch were recorded at 21 locations during this survey, and new records for the species were collected from five sub-catchments. All except one of these 21 sites were within National Park or Sydney Catchment Authority restricted areas.

The inaccessibility of many of these locations, and the added protection of the surrounding land from environmental disturbance, gives the illusion that fish populations in such streams are generally free from threatening processes. However most of the Hawkesbury-Nepean's major tributaries begin outside of this protective umbrella. As a result, they continue to be subjected to a number of threats in their 'upstream' reaches including flow regulation, pollution, impacts from introduced and translocated species, and habitat degradation such as sedimentation.

Predicting movement to Macquarie perch

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As a result of the prolonged drought, a new dam will be constructed in the Cotter Catchment to provide increased domestic water supply to the Australian Capital Territory. This will inundate critical Macquarie perch (*Macquaria australasica)* spawning habitats. Macquarie perch will only spawn in lotic environments and measures must be taken to ensure that access is available to riverine spawning sites upstream of impounded waters of the new dam.

This project will map and investigate the restrictions caused by fish barriers under different flow regimes To determine connectivity within the Cotter River network, we propose to develop model based upon terrain attributes to predict the location of physical barriers. Using DEMs and GIS, the predictive factors of slope, geology, and curvature will be used to classify areas of low/medium/high probability of finding a barrier. Field reconnaissance will be performed to physically identify barriers and assess the accuracy of the model. Once barriers are identified, the hydraulics over the barrier will be measured under different flow regimes. The mapping of barriers will identify areas in need of remedial or management works to facilitate fish passage past barriers, increasing spawning opportunities for Macquarie perch dispersal.

The loss of emergent macrophytes: a housing crisis for Macquarie Perch?

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A remnant population of Macquarie Perch is located in Cotter Reservoir, within the Australian Capital Territory. Stable, long-term water levels in Cotter Reservoir have facilitated the establishment of large stands of emergent macrophytes around its perimeter. The planned enlargement of Cotter Reservoir and future operation of the dam is expected to impede establishment of emergent macrophytes. Previous study has shown that emergent macrophytes provide daytime refuge for adult Macquarie Perch; however, habitat in the reservoir has subsequently been altered by the addition of large amounts of woody debris post bushfires in 2003. The current study is investigating the role of emergent macrophytes in providing refuge to adult Macquarie Perch. Fortnightly, radio-tracking was used to identify diurnal habitat use in the presence and absence of emergent macrophytes (based on manipulation of water levels). Emergent macrophytes are the second most commonly used habitat when accessible, whereas, woody debris is commonly used at high and low water levels. Emergent macrophytes were most commonly inhabited by the largest fish, whereas, woody debris was inhabited by adult fish from more diverse sizes. These findings have implications for the sustainable enlargement of Cotter Reservoir and management of an endangered species.

A research program for Macquarie perch in response to the construction of a new dam

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In response to the ongoing drought and bushfire impacts, the ACT Government has committed to the construction of a new domestic water supply dam for Canberra. Planning and design has commenced for the new dam, which will effectively enlarge and inundate the existing Cotter Reservoir on the lower Cotter River. The new dam will be 50 m higher than the existing dam, and impound an additional 4.5 km of river, with construction to be completed by late 2010. In the ACT, Cotter Reservoir contains the last viable population of Macquarie perch (*Macquaria australasica*) a nationally endangered species, and the enlarged dam poses a number of threats to this species. A research program to investigate and mitigate these threats has commenced, with four major projects underway:

- the suitability of artificial habitats for daytime shelter

- the swimming speed of various life stages
- a translocation program to establish additional populations
- determination of the status of EHN virus in the catchment

In addition to these, a PhD project investigating the impacts of cormorant predation on the population, and a Masters project examining the utilisation of a fine-scale Digital Elevation Model to predict migration barriers have commenced. This presentation will detail the threats posed by the enlarged dam, and outline the scope of the four major research projects to address them.

FRESHWATER FISH – MOVEMENTS

Insights into the swimming capacity of Murray cod

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Swimming capacity, encompassing both performance and energetics, is a key trait that influences the distribution and evolutionary fitness of all fish species. More specifically, swimming capacity is a key determinant of a fish's ability to avoid predators and unfavourable conditions, seek and defend habitat, and to find and capture prey. Measures of swimming performance such critical swimming speed (U_{crit}) and recovery ability often reflect ecologically important thresholds. Similarly, as swimming is an energy-demanding activity, energetic aspects such as optimal swimming speeds (U_{opt}), cost of transport (*COT*), and scope for activity (*SFA*) provide comparative measures related to the ecological demands of wild fish. Gaining a greater understanding of individual species' swimming capacity is therefore critical if we are to define management or habitat restoration actions at an appropriate scale.

Here we present preliminary data on changes in the swimming capacity of a large sit-and-wait predator, the Murray cod (*Maccullochella peelii peelii*), with key parameters (water temperatures and flow velocity) compared across body weight. Our results indicate that Murray cod are capable of moderate prolonged swimming (U_{crit}) becoming more energy efficient (U_{opt}), as temperature increases, but comparably less efficient as they increase in size (due presumably to hydrodynamic considerations). They maintain a low standard and active metabolic rate and small scope for activity (*SFA*) across temperature. The preliminary results of this study suggest that Murray cod employ a strategy of energy conservation in the face variable temperature and flow velocity regimes experienced within the Murray-Darling Basin.

Movements of the endangered trout cod

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We used radiotelemetry and mark-recapture tagging to determine the spatial movements of adults and juveniles of the endangered trout cod to assist in its conservation management. Trout cod exhibited strong evidence for site fidelity and homing in this study, typically utilizing

only a few locations in the river channel and undertaking limited movements. These limited movements indicate that the species is not highly dispersive at these stages and this has implications for population re-establishment and habitat recolonization. While increased movement occurred during the October-November period, there was no evidence of an obligatory migration during or prior to their spawning period. Significantly, several fish moved from the main river channel into floodplain channels during high flows. To ensure rapid colonization, habitat restoration such as the reinstatement of instream wood needs to occur in close proximity to source trout cod populations and for effective connectivity, distances between habitat patches should be minimized. Dispersal from populations may be expected to be limited and slow and habitat restoration combined with translocation may be a sensible option.

Seasonal movement of New Zealand koi carp (*Cyprinus carpio)*

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Koi carp, a highly coloured variant of the common carp (*Cyprinus carpio)* are an invasive alien species in New Zealand. The introduction and proliferation of koi carp to the lower Waikato River and connecting lakes and wetlands has degraded an already fragile ecosystem. To develop an understanding koi carp movement in the lower Waikato basin that might lead to effective population control we used a combination of acoustic and radio telemetry. We implanted 50 fish with Vemco acoustic transmitters and monitored them using 18 VR2 receivers. We implanted an additional 20 fish with HABIT radio transmitters and manually tracked them weekly for 14 months to date. Acoustic transmitters were implanted in May 2007 radio transmitters were implanted in July 2007. Koi carp occupied home ranges of less than 1 km for much of the year but the majority of fish migrated between 10 and 116 km at least once during the year. Fish dispersed a total of 164 km from the tagging locations with individuals travelling as much as 232 km a year at rates of up to 13 km/day.

FRESHWATER AND ESTUARINE FLOWS

Freshwater fish and environmental flows in the Macquarie Marshes

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Freshwater fish in the Macquarie Marshes, central western NSW, are sustained by relatively small environmental flows delivered haphazardly and without adequate monitoring of ecological responses. Our aim is to encourage a shift to more tactical flow delivery methods by providing ecological information on native fish communities, from population status and health to fish movements, feeding and reproduction. This presentation details recent advances in two critical areas: (a) the management of low-flow refugia during droughts; and (b) the management of barriers to fish passage in the lower Macquarie River. Fish surveys were conducted at ~20 sites during October 2007, following several years of extremely low flows, and again in March 2008, after a summer of good rainfall and a 23 000 ML environmental flow allocation. Some species recolonised the system from low-flow refugia (e.g., gudgeons, carp and goldfish), whereas others migrated from adjacent creeks and rivers (e.g., bony bream). Golden perch juveniles (~45 mm) were present in March 2008, indicating that spawning had occurred over summer. In May 2008, an aerial survey of the Marshes discovered more than 20 unlicensed barriers to fish passage (e.g., weirs, culverts and rock walls). These results are being incorporated into a Decision Support System (underpinned by spatial models linking rainfall, flow and floodplain inundation patterns) that will allow natural resource managers to predict the ecological outcomes of various environmental flow delivery options.

Environmental flow releases – effects on the lower Gwydir fish community

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The profound changes to the hydro-regimes of most rivers of the Murray-Darling Catchment (MDC) are thought to have played a major role in the decline of native fish populations. The timing, magnitude and duration of floods can play a crucial role in native fish recruitment. Environmental contingency allowance (ECA) flows might ameliorate some of the negative impacts of river regulation by mimicking natural flow patterns with the hope of improving riverine ecosystems and ultimately to restore native fish communities. We examined the structure of fish assemblages across multiple sites in the lower Gwydir system in north-western NSW over two years to assess the effectiveness of ECA's to restore native fish

communities. Particularly, we hypothesized that ECA releases would increase native fish abundance and diversity in the lower Gwydir system.

There was considerable spatio-temporal variation in the lower Gwydir fish assemblages. The diversity and structure of fish assemblages was closely associated with habitat quality. ECA's and other high flow events seemed to have only minor effects on the fish assemblages. However, there was a strong increase in fish numbers in the second year, coinciding with increased median flows. This suggests that stable base flows might be beneficial to the recruitment of some fishes. These findings have direct implication to the management of native fish populations in the MDC. The limitation of native fishes by habitat quality shows that the restoration of flows alone might not achieve the desired outcome to improve native fish populations.

The influence of wet season freshwater flow on the movement of barramundi (*Lates calcarifer*) caught in a dry tropical estuary

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We examined the $^{87}Sr/^{86}Sr$ isotope ratios in otoliths of commercially caught barramundi (*Lates calcarifer*). Sampling took place over four years in the Fitzroy River, in central Queensland. The Fitzroy River is a regulated tropical river with a tidal barrage existing ~ 50 km from the estuary mouth, defining the upper limit of marine tidal water intrusion. Isotope ratios in otoliths were used to reconstruct movement patterns of barramundi between estuarine and freshwater habitats. The movement of year-classes was related to the timing and quantity of freshwater flow events that occurred. Juvenile (0+) fish moved more than older fish. Movement of juvenile (0+) fish were significantly greater when freshwater flows occurred during the wet season (December – May). Movement patterns in older fish (1+ and 3+ were also correlated with wet season flow in the spawning year). The timing of freshwater flows and the potential implications on various lifecycle stages of estuarine populations need to be considered by water managers when attempting to address water efficiency targets.

The influence of freshwater flow on salt-wedge dynamics and fisheries productivity in the Gippsland Lakes

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Over the past decade there has been a dramatic decrease in rainfall due to the changing climate. This has resulted in less freshwater flowing from the catchments into the estuarine habitats. Freshwater flow into estuaries is important as it controls the extent and dynamics of the freshwater-saltwater interface (salt-wedge), which is a region of high productivity critical to the survival of larval fish. It is of major concern that there is little knowledge of how freshwater flow impacts the productivity of estuaries. In this study I aimed to determine the impact of freshwater flow events on the production, survival and growth of several key fishery species including black bream, *Acanthopagrus butcheri*, estuary perch, *Macquaria colonorum* and Australian anchovy, *Engraulis australis*. In the spring/summer of 2007 I used oblique plankton tows to determine the location and timing of spawning events in relation to the physico-chemical structure of the salt-wedge. During late September estuary perch began to spawn high up the Mitchell River within salinities ranging from 10-14 ppt. Bream began spawning in the Mitchell, Nicholson and Tambo rivers in early October when the salinity and temperature had risen to 17 ppt and 18°C respectively. Bream and anchovy spawning peaked in late October when the salt-wedge was highly stratified and well up the rivers. Eggs that were spawned in waters with greater than 50 % dissolved oxygen waters appeared to be healthier than those spawned in water with less than 50 % dissolved oxygen. These results suggest that salinity and temperature, and consequently freshwater flows control the location and timing of spawning events in the Gippsland Lakes.

Impacts of freshwater flow on catch rates of estuarine fisheries resources in NSW

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The freshwater flow requirements of estuarine fisheries remain poorly understood in Australia. Here we examined relationships between drought declaration, rainfall, freshwater flow and

fisheries catch rates to access the impacts of freshwater flow on estuarine fisheries production in NSW. Nine estuaries with distinct hydrological characteristics (three estuaries each with high, medium and low freshwater inflow) and varying degrees of freshwater regulation were selected for investigation. Monthly catch per unit effort from gill netting was used to infer the abundance of five commercially important species of estuarine-dependent fish: yellowfin/black bream (*Acanthropagrus australis/Acanthropagrus butcheri)*, dusky flathead (*Platycephalus fuscus*), luderick (*Girella tricuspidata*), sand whiting (*Sillago ciliata*) and sea mullet (*Mugil cephalus*).

Estuarine-dependent fish species appear to be influenced by variation in freshwater flow, in ways that may effect fisheries production due to changes in recruitment and catchability. Freshwater flow *per se* may not be as important in determining estuarine fisheries production as extremes in the hydrological continuum. Fisheries-flow relationships are discussed, with reference to important aspects of the flow regime for maintaining estuarine fisheries production. Reductions in freshwater flow arising from environmental flow regulations and climate change could have adverse impacts on estuarine fisheries production in NSW. While riverine enhancement of fisheries production seems clear, the exact mechanisms through which this occurs are not. Further research is required to provide an improved understanding of how freshwater flow produces such a marked influence on estuarine fish communities.

FISHERIES MANAGEMENT

Management for sustainable fisheries – strengthening regional and national capacity in the Pacific

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Our Fish, Our Future - the statement made by Pacific Leaders after the 2007 Pacific Forum, highlighted the growing regional concerns about the status of key oceanic and coastal fisheries resources, growing conflicts between national aspirations for the development of viable and sustainable domestic fisheries and increasing pressures from distant water fishing nations. There is a growing realisation of the need to plan strategically to meet national food security needs, that production for coastal fisheries will not be sufficient to meet household requirements for protein as island populations grow, and increased local access to production from nearshore and oceanic fisheries and aquaculture will be essential.

There are significant challenges facing the regional fisheries management bodies, such as the Western and Central Pacific Fisheries Commission, and regional agencies including the Forum Fisheries Agency and the Marine Resources Division of the Secretariat to the Pacific Community. There are also significant challenges facing the 20 Pacific island countries in managing oceanic, coastal and freshwater fisheries for which agencies carry national, provincial or local responsibilities and which are so important in subsistence, employment and local and export markets.

Australia is a major donor in the region. With a commitment by the Australian Government to a significant scaling up of its aid budget, AusAID is developing a more strategic approach to its engagement in fisheries-related aid, in its support for key regional bodies and national marine resource agencies, and in the development of partnerships with other donors and with agencies and institutions in Australia.

A Rolls Royce for the poor? Introducing a quota management system to a small-scale reef fishery

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A quota management system (QMS) is about to be introduced in Tasmania to the small-scale and low-value fishery for banded morwong *(Cheilodactylus spectabilis)*, a long-lived sedentary reef fish that occurs around south-eastern Australia. Over the past 15 years, a range of

management controls have been progressively implemented to this fishery, namely keyhole size limits, seasonal spawning closure, restricted entry and limitations via licensing. Although catches have stabilised at 40-50t in recent years, a large amount of latent effort still exists and could be activated with market expansion. In addition, a recently developed spatially-structured population model indicated concerns about the current stock status. While the data for the stock assessment were limited and uncertainty of model estimates was high due to the unknown spatial distribution of fish, the model consistently predicted that the biomass of old fish in the main fishing areas had strongly declined and that the fishery was now mainly recruitment driven. A risk assessment predicted likely declines of biomass under current catch levels and only a 50% chance of stabilizing biomass under a catch of 20-30t. Based on the scientific assessments, the fishing industry and fisheries management jointly agreed on a QMS with allocated catch quotas. The QMS will apply only to the core fishing areas and include individual assessment regions to avoid concentration of effort. The system must also be designed to be low-cost yet effective. While its implementation is a challenge for management and the industry, a successful QMS could serve as model for other small-scale fisheries.

A bio-economic management strategy evaluation of a multi-species, multiple-fleet fishery

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A bio-economic analysis was conducted for three fisheries using a multi-species size-based meta-population model. Effort dynamics of these fisheries were governed by catch rates and fleet profitability. The model was customised to emulate the Clarence River estuary and surrounding ocean waters in northern New South Wales (NSW) and calibrated against 23 years of catch and effort data from this region. The model examined the impact of nine economic scenarios involving various combinations of input costs and product prices. The analysis presented here suggests that these fisheries associated with the Clarence River are highly susceptible to changes in the price of the produce and that the dramatic fall in ocean trawl catch and effort in 2005/06 was more likely a result of stagnant product prices and a possible periodic downturn in long term recruitment of eastern king prawns than the much publicised rise in fuel prices. A number of alternative management strategies, including the use of more selective gear and effort quotas, were evaluated for their implications upon the relative profitability of the estuary and ocean trawl fleets as well as the robustness of these strategies to economic fluctuations. Very little separated the various management strategies in terms of their effect on overall regional income, however some of the strategies resulted in a redistribution of income between the estuarine and oceanic fleets.

Assessing and improving spatial harvest strategies to facilitate stock recovery in the Gulf St Vincent Prawn Fishery

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The western king prawn, *Penaeus (Melicertus) latisulcatus*, is a short-lived, highly valued crustacean that exists at its latitudinal (and temperature) limit in South Australia's unique gulf systems. The Gulf St Vincent Prawn Fishery (GSVPF) experienced a dramatic decline in catch and CPUE between 2000/01 and 2002/03 and in September 2004 fishers agreed to embark on a program of stock recovery. Since 2004/05, the biomass on which the GSVPF is based has increased substantially, due largely to the development of conservative spatial harvest strategies aimed at ensuring a viable spawning biomass and linking exploitation to increases in relative biomass.

Spatial harvest strategies are developed using fishery-independent survey data collected prior to each of four fishing periods. There are three stages in the process: 1) the maximum level of fishable area is determined from relative biomass indices (survey catch rate), 2) spatial harvest areas are identified that include target size prawns at suitable catch rates, and 3) harvest strategy adjustments are made during fishing in response to sub-optimal prawn size or low catch rates.

Whilst the recently updated Management Plan provides a useful framework for developing and adjusting harvest strategies, considerable challenges have been encountered during the evolution of this process. The annual stock assessment report provides the formal opportunity for assessment and improvement of harvest strategies, as well as underpinning assessment of the fisheries performance against the objective of stock recovery.

REPRODUCTION AND GROWTH

Studies of "gills, guts and gonads." Is classical fisheries biology no longer important or more crucial than ever?

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On occasion, my colleagues and I have heard various statements implying that classical studies on aspects of the biology of individual fish species, such as of their age and growth, reproduction and dietary composition, are now of lesser importance than other areas of research to fisheries management. In support of this notion is the sometimes presented simplistic argument that, as past fisheries management based on single-species stock assessments has seen many failures, we must now move towards more ecosystem-based fisheries management approaches. I argue that the validity and usefulness of both ecosystem-based and single-species fisheries models, which should be complementary, depends on the reliability of their data inputs, and that much of those data are derived from detailed fish biological studies. In saying this, the value of EBFM cannot be understated. In Western Australia, the fisheries department and WAMSI are leading the science and evaluation around this approach, for which they are to be commended. However, the jury is still out as to the quality of the data required to drive successfully the full value of this process. Ultimately, a judgement needs to be made about the relative importance of high quality data and science inputs to the EBFM evaluation in delivering key outcomes for ecosystem performance and evaluation. I highlight the importance of detailed fish biological studies to current fisheries management in Western Australia. I further provide an example which demonstrates how detailed biological studies can provide important insights into the state and functioning of aquatic ecosystems.

Inter-annual and spatial variations in the spawning patterns of sardine, Sardinops sagax, off southern Australia

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Data on the reproductive biology of the Australian sardine, *Sardinops sagax*, in gulf and shelf of South Australia have been collected since 1998. This paper quantifies inter-annual and spatial variations in key reproductive parameters, including size at sexual maturity, seasonality of spawning, rates of egg production (i.e. spawning frequency and batch fecundity) and spatial distribution of spawning activity. General Additive and Generalized Linear Models are used to identify correlations between reproductive parameters and physical and biological factors,

including mean monthly sea surface temperature (SST), upwelling strength, water depth and spatial patterns in SST, chlorophyll-a concentration and zooplankton abundance during the spawning season. Findings are discussed in relation the potential effects of climate change on the distribution and abundance of sardine off South Australia.

Reproductive biology of the Goolwa cockle *Donax deltoides* in the Coorong region, South Australia

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In the Coorong region of South Australia there is an important commercial coastal fishery for the Goolwa cockle (*Donax deltoides*). The annual catch in this fishery increased from 302 to 1103 tonnes between 1989/90 and 2004/05. This increase in total catch volume has coincided with a decline in catch per unit effort (CPUE), suggesting that biomass may be decreasing. At present there is limited understanding of the life history and population biology of this bivalve in this region, which hinders determination of the appropriate science-based fishery management protocol.

This presentation describes the reproductive biology of the Goolwa cockle, with particular reference to spatial and temporal variability. A number of parameters were investigated: sex ratios, size at maturity, macro and microscopic gonad staging and a number of microscopic quantitative parameters – oocyte diameter, oocyte area and oocyte density.

Sampling was undertaken from December 2005 to March 2007 at selected locations on a high energy coast near the mouth of the Murray River. Other physical and biological parameters were investigated to assist in understanding the trends found in this exposed variable environment. It is anticipated that an understanding of the reproductive strategy of Goolwa cockles will help to interpret responses to fishing pressures. The outcomes will assist fishery managers make more informed decisions on the management of this fishery.

Reproduction and growth of dusky flathead (*Platycephalus fuscus*) in NSW estuaries

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P. fuscus inhabits estuaries and nearshore coastal waters along the east coast of Australia between Cairns in Queensland and the Gippsland Lakes in Victoria, where it is an important finfish species harvested by recreational and commercial fishers. Due to concerns over the long-term sustainability of the resource in NSW, the minimum legal length (MLL) of dusky

flathead was increased from 33 to 36 cm total length (TL) in July 2001. Prior to any further potential increases, greater information concerning aspects its biology is required.

P. fuscus were sampled from various locations throughout NSW between 2001 and 2006 to investigate aspects of their biology to assist with management. *P. fuscus* has an extended period of reproductive activity, peaking between November and March. It was estimated that the length at which 50 percent of the population is mature (L50) between November and March was 31.72 cm TL for males and 56.75 cm TL for females. The corresponding estimated age at which 50 percent of the population is reproductively mature (A50) was1.22 years for males and 4.55 years for females. Females grew faster and attained a greater overall maximum TL, weight and age than males. The largest observed female was 98.5cm TL (7.5 kg), and the oldest was estimated to be 16 years, whereas the largest male was 61.5cm TL (weight) and 11 years of age. Although the growth rates and maximum attained lengths varied between sexes, the relationship between length and weight of fish did not differ between sexes.

Spatial variation in growth and condition of Victorian black bream, *Acanthopagrus butcheri*

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Black bream (*Acanthopagrus butcheri*) are a common fish species throughout estuaries in Victoria. They rarely leave the estuarine environment and different populations are considered to exist within different Victorian estuaries. Limited movement combined with widely differing environmental conditions within the estuaries likely results in marked differences in growth rates and condition, which has been reported previously for several isolated black bream populations in Western Australia. In this study black bream were collected from four different estuaries within the Port Philip Bay region: The Yarra, Maribyrnong, Werribee and Little Rivers. Growth rates, condition indices and morphometric measurements in black bream from this region are discussed in relation to other Victorian black bream data to evaluate differences in the sampled populations.

FISH MOVEMENTS AND OTOLITH CHEMISTRY

High connectivity of coastal fish farms through wild fish migrations may limit coastal aquaculture

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Conventional management of the extent of coastal salmon farms relies largely on ecological knowledge of nutrient impacts, the effects of escaped salmon, and the role salmon farms play in sea lice infestations of wild salmonids. Wild fish closely associate with fish farms and have long been suspected to act as disease vectors among farms, in a similar fashion to the spread of bird flu by migrating wild birds. Here we show that wild coastal fish species use salmon farms as a highly connected series of habitats. Using underwater video, we estimated that mixed aggregations of wild cod, saithe and haddock occurred in biomasses of tons to tens of tons within metres of the cages at 7 of 9 farms investigated in intensive salmon farming regions throughout Norway. Acoustic tagging and tracking of 24 saithe (*Pollachius virens*) in northern Norway revealed rapid and regular migrations among adjacent farms; 70% of tagged saithe migrated among three farms spaced 4 to 8 km apart. Within three months, 16 saithe made an average of 8 inter-farm movements at maximum speeds of 4 km hr-1. Wild fish share a range of pathogens and diseases with farmed salmon, including salmonid alphavirus and sea lice, which cause serious production losses. If wild fish act as significant disease vectors, the direct connectivity of salmon farms through wild fish migrations may restrict aquaculture in coastal waters.

The potential use of otolith shape and microchemistry to distinguish cod species (Genus *Pseudophycis*) in the diet of Australian fur seals

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Otolith shape is often used to facilitate the identification of teleost prey species in marine diet studies. However, fine-scale variation in otolith shape among different species, and the added effect of partial digestion of otoliths, can often limit the ability to identify prey species. The objective of this research was to evaluate the potential use of 1) fine-scale shape differences using Fourier shape analysis and 2) microchemical differences using laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS), in digested otoliths to identify fish prey

species within the diet of predators. Belonging to the family Moridae, red cod *Pseudophycis bachus* and bearded rock cod *Pseudophycis barbata* are found in the shelf waters of south-eastern Australia and New Zealand. *Pseudophycis* species are important to a range of predators including the Australian fur seal (*Arctcephalus pusillus doriferus*) at Phillip Island Australia. *Pseudophycis* species from within the foraging range of the Australian fur seal at Phillip Island were examined for evidence of species-specific differences in otolith shape and microchemistry, with the objective of using these differences to identify prey species using otoliths collected from seal faecal and regurgitate samples at the Phillip Island seal colony. The results revealed that the use of otolith shape analysis techniques to identify prey species where otoliths have fine-scale shape differences was found to be effective however should be used with caution as the effects of digestive processes can be significant. The use of core-region otolith microchemistry as a method to distinguish prey species was also found to be effective, and furthermore showed potential to provide a means to establish more direct links between predators and the geographical source of their prey.

Recruitment and migration patterns in New Zealand trout populations – an analysis using otolith microchemistry

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New Zealand trout populations display a highly plastic life history. Trout can form resident or migratory populations in streams, rivers, lakes, estuarine and near shore marine environments. However, spawning usually occurs in various upstream tributaries that provide suitable conditions for egg and larval development. To reach these spawning grounds, long distance migrations are often necessary. The high mobility of adult fish and the uncertainty in locating important recruitment areas in large catchments provides extra challenges to the successful management of trout populations.

We analysed micro-chemical patterns in otoliths of adult and juvenile trout using laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS) to investigate trout life history patterns in several South Island Rivers.

We were able to construct habitat specific micro-chemical signatures from the analysis of juvenile trout otoliths which could successfully be matched with the signatures of adult fish. This allowed the identification of likely natal rearing streams and lifelong migratory behaviour of individual fish. The results indicated that certain tributaries are more important for recruitment then others, and that populations usually recruit from a variety of tributaries. Large-scale migratory behaviour was common in all trout populations. However, the occurrence of 'sea run' fish reared in an estuarine or marine environment was less common than is often presumed. These results will be helpful in successfully managing trout

populations by the identification of recruitment hot-spots and the persistence of long distance migratory behaviour.

Age-related movement patterns and population structuring in Southern Sea garfish (*Hyporhamphus melanochir*) inferred from otolith chemistry

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The southern sea garfish (*Hyporhamphus melanochir*) is an important inshore fishery species in South Australia. Over the past few years, there have been significant concerns with this fishery. Currently, the fishery is assumed to consist of two separate stocks, however there is no understanding of movement patterns both within and between these two stocks to justify this assumption. This study uses otolith chemistry to infer age-related patterns of movement, delineate potential sub-populations, and determine the extent of mixing within South Australian coastal waters. Results indicated that the population structuring of garfish is more complex than previously assumed and it seems that stocks can be discriminated at a much finer spatial scale. Garfish collected from sites separated by <60 km displayed significantly different chemical signatures (relative concentrations of ^{7}Li, ^{24}Mg, ^{55}Mn, ^{88}Sr, ^{138}Ba) in their otoliths, especially during their second year of growth, indicating that they had inhabited different water bodies. From a broader perspective, South Australian garfish can be partitioned into six regional components with various levels of inter-mixing. From these results it was suggested that assessment and management of the fishery may have to be restructured to align with the smaller spatial units.

Evidence for fine-scale population structure in the eastern Australian salmon (*Arripis trutta*) stock provided by otolith chemistry

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Otolith chemistry, otolith shape and tag-recapture data were used to provide a preliminary examination of the population structure of the eastern Australian salmon stock in SE Australian waters. Five year old salmon for otolith chemistry and shape analyses were collected from four locations: northern NSW, southern NSW, Victoria, and Tasmania. Otolith shape was determined with Fourier analysis and combined with measures of otolith area and perimeter. Various indices of shape were compared between locations (n=15 per location). There were no differences in otolith shape between fish sampled from NSW (north or south) or Victoria,

however fish collected from Tasmania had significantly shorter otoliths. The cores and edges of otoliths from salmon collected from two sites in each location (n=10 per location) were spot-analysed using LA-ICPMS. Univariate analyses found no spatial differences for any of the elements Li, Mg, Mn, Ba or Sr. Multivariate analyses however, did find a significant difference in the elemental 'fingerprints' of fish from each of the locations, with fish from Tasmanian waters having the most distinct 'fingerprint'. Further analyses showed that fish collected from one of the Tasmanian sites (Flinders Island) were significantly smaller than fish from all other sites, suggesting reduced growth rates for this group of fish. Extensive tag-recapture studies done during the 1960s demonstrated widespread mixing of the salmon population in SE Australian waters and established a robust model of general movement of fish from Tasmanian waters north to Victoria and NSW with the approach of sexual maturity. These studies also suggested that a portion of the stock of salmon in Tasmanian waters is possibly resident and does not undergo the northerly movement generally observed. The result of using natural chemical markers in otoliths presented here suggests some fine-scale stock structure and supports the model of a potentially resident sub-population of salmon in Tasmanian waters.

AGEING AND GROWTH

Telomere Length: A potentially non-lethal fish ageing tool?

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Accurate determinations of the age of fish (teleosts and chondrichthyans) are critical for the conservation and management of endangered and exploited populations. However, current methods for ageing fishes are time consuming, subject to error, are not possible in some chondrichthyans, and generally require the destructive sampling of specimens; therefore, the development of novel non-destructive ageing techniques for fishes are imperative. We investigated the use of telomere length as a non-lethal means of determining the ages in a range of free-living fish species, by examining relationships between telomere length and age. No significant relationships between telomere length and age were identified in the chondrichthyan species examined. Further investigations into a range of tissues suggest that chondrichthyans possess mechanisms that maintain telomeres at near constant length, throughout their lifespan. Significant relationships between telomere length and age were identified in some species of teleosts. We conclude that telomere length is a suitable age determinate in some species of teleosts. However, due to the complexities of the telomere ageing protocol, the general application of this method may be limited to species which are otherwise unsuitable for conventional increment based age determination (i.e. species of high conservation value).

Density-dependent growth; evidence, complexities and management implications

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Many studies focus on compensatory responses of fish populations to changes in density. Density-dependent fecundity and juvenile survival are generally considered the key drivers of population regulation, but many fish species exhibit variation in growth with density as well. Some authors attest that density-dependent growth should also be recognized as a key contributor to the regulation of fish populations.

This review examines the intricacies of density-dependent growth research and finds that analyses of density-dependent growth appear more commonly in aquaculture than in wild fisheries. This is likely due to practical difficulties with field manipulations of population

density and with separating density-growth relationships from the influence of environmental change. The frequency of density-dependent growth in farmed situations though suggests that further attention should be directed to wild fisheries.

Studies of density-dependent growth employ a variety of methods and reveal a wide range of cause and effect relationships. Variation in density for example can lead to changes in the growth rate of individual fish or in changes only to asymptotic size. Variation in growth might be observed in the adult or juvenile phase alone or across the entire lifespan of an individual. Further, density-dependent growth might be influenced by cohort, year class or total population abundance. If density-dependent growth is to be considered a key process in the regulation of fish populations and accounted for in fisheries assessments, we need to determine which cause and effect relationships have important consequences for the regulation of populations.

Growth of the eastern school prawn *Metapenaeus macleayi* in New South Wales waters

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The eastern school prawn is endemic to the east coast of Australia. It contributes approximately 41% and 22% by weight and value respectively, to the wild caught prawn production each year in New South Wales. Growth of this species was examined at in estuarine and ocean waters in two areas in New South Wales. Length data from monthly, fishery independent surveys over two years were analysed for monthly cohorts and the mean length for each cohort was calculated. Growth was modelled by fitting mean length data to a re-parameterisation of the von Bertalanffy growth function to include seasonal growth. Goodness of fit of the model to the data was determined by minimum likelihood techniques. Results will be discussed.

Systems and methodologies for accurate fish ageing at NSW DPI

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There are two fundamental goals for any fish ageing laboratory. The first is to have appropriate facilities to obtain speedy, yet repeatable age estimates. The second is to have procedures and standards in place to ensure accuracy and scientific rigor in the age estimates derived.

The Cronulla Fisheries Research Centre ages over 5 000 fishes per year. To achieve rapid, yet accurate, age estimates, we use an integrated system of data entry combined with a series of rigorous protocols to ensure reader accuracy. Our physical systems consist of real-time image

analysis which directly uploads into a central database. Our software captures the otolith image, and calculates ring count and ring increment with nothing more than a few clicks of a mouse. Our reader protocols ensure quality age estimates through training and assessment before, during and after age counts. This is achieved by training with annually-updated reference collections, reviewing otolith interpretation while undertaking age estimation and re-counts of a subset of the data once reading is complete.

The ageing protocols at the Cronulla Fisheries Research Centre provide an efficient, cost-effective technique for rapidly undertaking large volumes of fish ageing at an international-standard of scientific rigor. We suggest our protocols would be suitable for large or small institutions wishing to maintain the integrity of their age estimations.

Evidence for age-class truncation in exploited populations of coastal fish in New South Wales

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The nearshore coastal fisheries of NSW have been exploited for more than 200 years. Exploited reef-associated species in NSW are typified in being long-lived (15 to 50 years) and maturing sexually at relatively young ages (2 to 4 years old). The benefits of longevity in these nearshore environments are thought to relate to a long reproductive life and occupying an ecological niche. These benefits are important for population persistence through periods of poor recruitment and in environments of relatively low productivity. The age compositions in landings of the major inshore species in NSW indicate age-class truncation and provide evidence of variable recruitment in some species. Highly sought-after species with long histories of exploitation (such as snapper, mulloway and kingfish) exhibit considerable age-class truncation, with relatively few fish greater than 5 years old in landings. In contrast, species that have traditionally been considered less desirable (such as sweep, red rockcod and pigfish) tend to have age compositions with relatively large numbers of older fish. While age-class truncation may seem to be an inevitable artefact of exploitation, its potential to weaken the resilience of populations should be acknowledged. Some options to control age-class truncation are presented.

SURVIVAL, RESTOCKING, ENHANCEMENT AND HABITAT

Distinguishing hatchery from wild produced fish based on elemental chemistry of otoliths

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Stocking of hatchery-produced fish is an integral component of fisheries management with applications for recreational and commercial fisheries, as well as conservation of threatened species. Once stocked, it is often difficult to distinguish hatchery-produced from wild-produced fish. We aimed to determine if natural elemental signatures can be used to distinguish hatchery from wild fish in rivers where stocked fish were marked with alizarin complexone; hence, the accuracy of otolith chemistry to correctly classify fish could be assessed. We predicted that the edge of the otoliths of the two groups (alizarin marked hatchery fish and wild fish) would be similar since the fish were caught at the same time from the same place, and that the centre of the otolith would differ given that the two groups of fish would have spent their early life in different waters (hatchery vs river). In addition, we also predict that the centre otolith chemistry of stocked fish would match that of Narrandera hatchery fish, since this was their origin. Results showed that the edge otolith chemistry was similar between the two groups of fish, and that the centre otolith chemistry differed. As expected, the centre otolith chemistry of stocked fish matched that of Narrandera fish. We then analysed the edge and centre of otoliths of fish collected from Billabong Creek, where around 100 000 un-marked fish had been stocked to determine which fish were stocked fish. Results showed that virtually all fish were from Narrandera hatchery. Information on the proportion of hatchery produced versus wild produced fish is essential for assessment of fish populations.

Stocking success and management of a recreational fishery, Glenbawn Dam, NSW, Australia

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Stocking is a management tool frequently used to enhance or create recreational fisheries. Determining the success of past stockings is essential in order to attempt to manage these fisheries. Many factors could affect the survival of stocked fish but these remain to be quantified.

We used incremental ageing techniques to determine year-class strength in a large coastal reservoir, Glenbawn Dam, in New South Wales. Year classes were correlated with environmental variables to determine factors associated with increased survival of stocked fish. Australian bass (*Macquaria novemaculeata*) and golden perch (*Macquaria ambigua*) live for up to 12 years but there were marked differences in growth rates for each species. There are large variations in length-at-age in both species. Australian bass took up to 8 years to reach 300mm whilst golden perch took up to 10 years. Survival of stocked bass and golden perch fingerlings did not occur every year. Both species were generalist carnivores preying on a variety of macrocrustaceans, insects and fish. Dietary analysis revealed high dietary overlap between both species suggesting increased competition for available resources.

Almost 2,000,000 golden perch and 1,000,000 Australian Bass have been stocked into Glenbawn dam. Previously managers have stocked without any information to assist in deciding the correct numbers to release. In some years, up to 500,000 fingerlings have been released and in other years as little as only 3,000 were released. This study will aid future stocking events by identifying factors which are most likely to result in the survival of stocked fish.

Post–release mortality, gonad development and condition of angled Australian bass, *Macquaria novemaculeata*

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Two key assumptions supporting the promotion of catch-and-release angling are that most fish (i) survive, and (ii) incur few negative long-term impacts. While recent research has validated the first requirement for many Australian species, few attempts have been made to investigate the potential for more subtle sublethal effects on the health of survivors. Of particular concern for some freshwater species, including Australian bass, *Macquaria novemaculeata*, is the impact of catch and release on their reproductive development during their annual spawning migration. In an attempt to address this issue, we investigated the effects of two extremes in angling treatments (mouth hooking and immediate release vs. hook ingestion and delayed release) on the post-release mortality, gonad development and condition of Australian bass during a pond experiment with recreational anglers. Subsets (n = 10-20) of each hooking treatment and a control group were destructively sampled and analysed at three times: (i) immediately prior to release; and (ii) one week and (iii) four weeks post-release. Compared to mouth-hooked and control fish, hook-ingested fish had higher delayed mortality (30% vs. 0 and 5%, respectively) and reduced feeding levels. Further, none of these latter fish shed their hooks after four weeks. Irrespective of their treatment, approximately half of all the fish did not start normal gonad development prior to, or during the experiment, possibly as a consequence of their initial collection disturbance (3-9 months beforehand). However, for

those fish that had maturing gonads at start of the experiment, being angled and released had little effect on further development. Additional research is required to assess the importance of the timing of angling in relation to the stage of gonad development and also, given the lack of any shedding of ingested hooks, the longer-term mortality and potential for delayed sublethal impacts to hook-ingested fish.

The conceptual basis for constructing homes for adult Macquarie perch in Cotter Reservoir

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Habitat can mediate predation and this is one of the likely mechanisms underpinning the persistence of a remnant population of endangered Macquarie perch in the Australian Capital Territory. Historically adults of this population have sheltered from cormorants by resting in emergent macrophytes during the day, within Cotter Reservoir. More recently adult Macquarie perch have shifted to also shelter in large woody debris that has been deposited in the littoral zone of the reservoir following a bushfire.

Cotter Dam is to be raised 50 m by 2010, to increase water storage for Canberra. Critical Macquarie perch habitat is vulnerable to the initial filling of the reservoir and dynamic water level fluctuations thereafter. This has ramifications under the EPBC Act. Therefore, we aim to identify suitable habitat for adult Macquarie perch in the reservoir prior to completion of the dam refurbishment, with the aim of incorporating such habitat into the dam construction program. We outline the conceptual basis for this research in an adaptive management framework.

Estuarine artificial reefs for recreational fisheries enhancement revisited: Lake Macquarie, NSW Australia – a case study

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Over 40 countries worldwide have constructed artificial reefs, with objectives for their deployment including enhancement of recreational and commercial fishing, coastal protection and mitigation of habitat loss and damage.

Lake Macquarie located between Newcastle and Sydney on the NSW central coast is closed to commercial harvest but open to recreational fishing. Artificial reefs were first trialled in Lake Macquarie in the 1960's using car tyres. In 2005, concrete 'Reef Ball' habitat modules were to create six small artificial reefs in Lake Macquarie. The artificial reefs were monitored between December 2005 and November 2007 using baited underwater video (BUV) and diver census.

Preliminary results of the Estuarine Artificial Reefs Monitoring Program indicate that large numbers of a diverse range of species are attracted to estuarine artificial reefs. Results also indicate that the use of baited underwater video (BUV) is an effective method for monitoring fish populations within estuaries and provides a cost effective means of carrying out future monitoring programs associated with artificial structures.

Although similarities between artificial reefs and naturally occurring reefs were evident, some differences in relative abundances and species diversity were observed. It is unclear whether these differences were a factor of the structural differences of the reef themselves or a result of species succession as the reefs evolve to stable community structure. Overall productive value of artificial reefs is difficult to measure. At a small scale, a localised productive increase can be inferred from the results; however the productive value of each reef over larger spatial scales was not addressed by this study.

Reducing the post-release mortality of angled snapper (*Pagrus auratus*)

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In response to concerns over the fate of angled-and-released snapper (*Pagrus auratus*), two experiments were done to quantify (1) their short-term mortality and the key predictors and then, based on these results (2) the effects of hook materials and designs on the survival of hook-ingested individuals. The first experiment was done in January 2008 in Botany Bay and involved 24 recreational anglers using conventional gear to target all sizes of snapper. Anglers placed their fish into individual cages (110 l), and completed a relevant datasheet. Appropriate numbers of controls were similarly confined, and all fish monitored over five days. All of the controls survived. By comparison, 13 of 156 angled-and-caged snapper died, providing a significant overall mortality of 8% ($P < 0.05$). Hook ingestion was identified as a predictor of mortality, with the effects significantly exacerbated during hook removal ($P < 0.05$). These results advocated cutting the line and releasing fish with their ingested hooks, but there were no data on their longer term fate, or if survival could be improved via the use of specific hook types. We addressed this lack of information during a second experiment at the National Marine Science Centre (Coffs Harbour) aquaria facilities, in which six groups of snapper (n = 18 in each group) ingested either conventional or modified (with small notches) Mustad size 2

hooks made from three materials (stainless steel and nickel-plated and red-lacquer carbon steel) and were monitored for 42 days. The total overall mortality was 25%. Of the fish that ingested the nickel and red-lacquer plated hooks, 69 and 64%, respectively ejected their hooks (over a mean ± se of 10.1 ± 2.1 and 5.7 ± 1.1 days) while 19 and 22% died. In contrast, only 36% of fish ejected stainless hooks (over 13.9 ± 1.7 days), but 33% died. The potential mechanisms causing these differences and directions for future research to improve the post-release fate of snapper are discussed.

NSW DPI's fish aggregating devices - from pilot study to permanent program

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Fish Aggregating Devices (FADs) are a popular fisheries enhancement tool, attracting anglers from the recreational sector including line and spearfishers as well as charter operators in NSW. FADs provide alternative fishing opportunities for anglers, arguably diverting effort from the more traditionally targeted inshore fisheries. In 2002 NSW DPI secured funding from the Recreational Fishing Trust to conduct a FADs pilot study and monitoring program.

Monitoring of FADs involved identifying fish species present on the devices, measuring catch rates, and evaluating the influence of physical factors such as current and water temperature. Results suggest that mahi mahi (*Coryphaena hippurus*) and yellowtail kingfish (*Seriola lalandi*) were the dominant species present on the FADs. Catch rates were not a suitable measure of abundance; however, catch rates were significantly affected by sea surface temperature.

Following the successful pilot study, the DPI FADs program has slowly expanded, with a number of new FAD locations added since 2002. Currently there are 21 FADs off the NSW coast with two devices deployed off Lord Howe Island. There are two additional FADs approved for deployment during the 2008/09 season, bringing the total number of NSW DPI FADs to twenty-five, the largest program in Australia.

This presentation will outline a brief history of the NSW DPI FAD program, highlighting the design of FADs and the approvals process required prior to deployment. The research carried out to date on the NSW DPI FADs will be discussed, as well as monitoring techniques that will be used for future research on these devices.

The influence of epibiota on the structure of temperate fish assemblages attracted to small experimental reefs in Swansea Channel, NSW, Australia

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In 2006-2007 the Roads and Traffic Authority, NSW, placed 5000 tonnes of quarry rock beneath Swansea Bridge as part of ongoing maintenance. Existing material with well developed epibiota from beneath the bridge was collected prior to the work for use in rehabilitation after completion of the work. The aim of this study was to investigate the assumption that the existing material with established epibiota would attract a more diverse assemblage of fishes than the quarry rock.

Experimental reefs were constructed within baskets adjacent to Swansea Bridge. Treatments included the existing material (old reef), quarry rock with no epibiota (new reef) and control treatments of empty baskets and bare sand. The fish assemblage was sampled fortnightly over a 2-month period.

There was no difference between the old reef, new reef and basket experimental treatments in the abundance, species richness and assemblage structure while the bare sand treatment had a lower abundance, species richness and a distinct assemblage during the first four surveys. During the final survey fish abundance was greatest for the new reef treatment. Concurrent monitoring of the epibiota showed a clear distinction between all four treatments.

The fish assemblage showed no preference for the presence of epibiota and it appears that structure was more influential on fish habitat selection. The results suggest that the quarry rock used in the stabilisation work is likely to support a similar fish assemblage to the previously existing rocky substratum.

Importance of location and habitat structure in determining nearshore faunal assemblages within Botany Bay, Australia

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Estuarine habitats are particularly susceptible to anthropogenic disturbance, however the consequences of habitat loss or alteration are unpredictable because processes determining distributions of nearshore small fish and macroinvertebrates are not well understood. In this study the importance of location and habitat structure (seagrass and patch reef) in determining nearshore faunal assemblages within Botany Bay, Australia, was investigated over

four years in a series of mensurative and manipulative experiments, incorporating different spatial scales (metres and kilometres).

Variation in fish and macroinvertebrate assemblages within natural seagrass (*Zostera capricorni*), artificial seagrass and patch reefs was investigated at a medium (1-2 km) and a broad spatial scale (several km) within Botany Bay. Potential confounding factors such as the sampling method and volume of 'living space' within each habitat were standardised in an experiment.

Location within Botany Bay and habitat structure were important in determining fish and macroinvertebrate assemblages within seagrass (*Zostera* and artificial beds) and on patch reefs. Faunal assemblages within the habitats were localised at the scale of site. Differences between macrofaunal assemblages in seagrass beds and patch reefs were evident over different spatial scales (metres and kilometres) and regardless of the large variability in faunal assemblages between sites. Most taxa found within seagrass beds did not recruit to the alternative habitat provided by patch reefs, indicating that the reefs were a novel habitat in areas dominated by seagrasses. Consequently, disturbance to seagrass beds within the bay by introducing artificial hard substrata may result in different faunal assemblages to those in seagrass beds.

Density dependent habitat selection in an estuarine finfish – consequences for stock enhancement

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The mechanics of density dependent dispersal is crucial to understanding ecological systems. In particular, understanding the consequences of excessive stocking density in terms of emigration, foraging behaviour and use of key habitat will help ensure stock enhancement programs are undertaken responsibly and within the ecological limits of the system. We conducted a large scale field experiment, manipulating density of mulloway *Argyrosomus japonicus* in the Georges River, New South Wales, Australia and compared emigration, foraging behaviour and habitat use for fish stocked under and over estimated carrying capacity of key habitats. Acoustic telemetry was used to both passively and manually track 36 tagged fish over a two week period. Mulloway stocked at high densities experienced emigration rates up to 17 times faster from their release site and the tracking area than those stocked at low density. Fish stocked at high densities spent more time in non-optimal habitat over the first six days post release. No differences were found in the fine scale movement (foraging behaviour) or home ranges between treatments of density. The final spatial distribution of mulloway agreed with the theory of Ideal Free Distribution, and available key habitat explained much of the observed behaviour. Key habitat rather than food resources are likely governing mulloway spatial distribution, thus key foraging and hiding habitat will need to be evaluated to determine carrying capacity in stock enhancement programs.

Habitat complexity affects habitat preference and predation mortality in post-larval eastern king prawns: Implications for stocking

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Attempts to ameliorate declines in Penaeid populations through stock enhancement have been made in several parts of the world and have recently been proposed for the eastern king prawn, *Penaeus plebejus*. The success of past enhancements has been restricted by limited knowledge on the availability of habitats that best support stocked populations and the mechanisms underlying survival and distribution of stocked species within these habitats.

We examined active habitat selection as a possible mechanism driving the distribution of *P. plebejus* and evaluated the species' mortality due to predation in different habitats. The results demonstrated that *P. plebejus* settle into complex and non-complex habitats randomly during the night, but actively select complex habitats over non-complex habitats during the day. We also found that mortality caused by predatory fish was higher in non-complex habitats than complex habitats. We posit that post-larvae select complex habitats during the day to lower predation risk, and that reduced predator efficiency at night precludes the need to shelter within complex habitats, which allows the post-larvae to forage in all habitats.

Based on our findings, we recommend that future releases of *P. plebejus* be conducted directly into complex macrophyte beds to optimize survival by minimizing predation mortality. Quantitative assessment of the carrying capacity of available macrophyte is also necessary, prior to stocking, to reduce competition for preferred habitat amongst stocked individuals and thereby optimize their growth rates. Such assessment may also ease competition between wild and stocked con-specifics and thus minimize the risk of significantly affecting the wild population.

Edge effects in patchy seagrass habitats: using video to sample mobile species

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Habitat edges can influence the distribution of fish in and amongst seagrass patches. However, sampling methods used to assess the influence of seagrass edges on fish distribution are often used at inappropriate scales to detect patterns or preclude sampling of mobile, fast moving fish, including large predators and commercial species. We used remote underwater video to assess the distribution of fish at four positions (seagrass edge, seagrass middle, adjacent sand, distant sand) within patchy seagrass habitats during the day and night. Remote underwater video can sample fast moving fish at small scales (1 - 3 m) appropriate to patchy seagrass habitats. Several methods were used to process fish recorded on video footage, and the application of each method to remote underwater video at small spatial scales will be discussed. During the day, distribution patterns of several species varied between seagrass positions, however, differences depended on the video processing method used. The predator *Arripis* sp., and the commercially important *Sillaginodes punctata*, were recorded over adjacent sand more than other positions, which may be related to feeding opportunities close to the seagrass edge. Our results show that seagrass and sand edges can be an important habitat for mobile fish, and that underwater video can be an appropriate sampling technique to assess fish at small spatial scale.

Fish responses to seagrass habitat fragmentation

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Australia's seagrass habitats support a large variety of recreationally and commercially important fish species. Fragmentation of seagrass habitats is increasing worldwide and poses a significant threat to fisheries. To understand the effects of fragmentation on seagrass-associated fish, we actively fragmented a series of artificial seagrass beds (single, continuous 9 m^2 patches into four, discrete 1 m^2 patches) and evaluated the effects on fish abundance and

species richness through time. Fish abundance and species richness did not change following fragmentation. We then measured fish abundance from edges (0-0.5 m) and interiors (0.5-1 m) of fragmented and continuous seagrass. Fish in continuous patches were more abundant at edges compared to interiors, but in patchy configurations there was no difference. This suggested that the loss of seagrass area caused by fragmentation was offset by an increase in edge habitat and positive edge effects. We then used a two-prong approach to test the hypothesis that fish are more abundant at edges due to greater food availability. The first approach involved measurements of food (small crustaceans) availability across continuous seagrass patches using plankton tube traps. The total abundance of crustaceans was higher at patch edges than interiors. The second approach involved supplementation of patch interiors with food using live artemia dispensers. Fish responded to supplemented food by moving from patch edges to interiors, while edge effects were maintained in controls. Together, these approaches support the model that fish are more abundant at seagrass edges due to greater food availability.

Succession of macroalgal communities on estuarine artificial reefs

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The NSW Department of Primary Industries is undertaking a pilot Artificial Reefs project to investigate the benefits of artificial reefs as a fisheries enhancement tool in Recreational Fishing Havens (RFH) along the NSW coast. Artificial reefs have been deployed in Lake Macquarie (December 2005), Botany Bay (June 2006) and St Georges Basin (February 2007) using concrete 'Reef Ball' habitat modules.

Many studies have focused primarily on fish assemblages on artificial reefs; however the macroalgal communities present on these reefs are an integral trophic link and an essential feature in the development of productive artificial reef ecosystems. This study is designed to complement the broader NSW DPI Estuarine Artificial Reef Program by providing a more comprehensive understanding of how variation in macroalgal communities between and within estuaries influences finfish assemblages inhabiting these reefs.

A photographic survey of the reefs will be used as the basis to analyse the succession of macroalgal communities associated with artificial reefs deployed in Botany Bay, Lake Macquarie and St. Georges Basin. I will provide an overview of this project and discuss the methodology proposed to examine temporal and spatial variation in algal communities associated with the NSW Estuarine Artificial Reefs.

Implications of barotrauma on the release of black jewfish (*Protonibea diacanthus*)

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A total of 108 black jewfish (*Protonibea diacanthus*) ranging in size from 34 to 125 cm total length and landed from three depth brackets: 0-10 m (n = 15); 10-15 m (n = 35); and 15-20 m (n = 58) were autopsied in order to describe the effects of barotrauma on this species. The examinations revealed that black jewfish are highly susceptible to barotrauma (regardless of fish size) and exhibit a range of conditions. These include: haemorrhage and exophthalmos of the eyes, hyperinflation or rupturing of the swim bladder (as a consequence of hyperinflation), displacement and damage to visceral organs and damage to the circulatory system. Black jewfish landed from less than 10 m showed few signs of barotrauma and were likely to survive if released. Forty six percent and 100% of black jewfish landed from 10-15 m and 15-20 m respectively, had injuries that rendered them unlikely to survive. These important findings have been translated into educational material available in hard copy or on the web and have featured on a nationally televised fishing show.

FISHERIES MANAGEMENT AND BIOLOGY

Using a suite of fishery-dependant sampling strategies to collect representative biological data for multiple species in the recreational fishery

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The DPI&F routinely collects biological information on key commercial and recreational species Queensland wide. This data is used to identify trends and to assess the effectiveness of fisheries management strategies. The monitoring programs for many of these species rely on the collection of representative data from existing commercial and recreational fisheries. The collection of representative data on a large number of species from a broad geographic range such as Queensland's East Coast requires a suite of sampling strategies. Currently DPI&F obtains biological information from the recreational sector through routine Boat Ramp Surveys, Roving Surveys, Charter Boat Catch Sampling, Competition Sampling and the Keen Angler Program. Due to the nature of the recreational fishery and the biological differences between species, the effectiveness of each sampling strategy differs between species. The following presentation will discuss species-specific strengths and weaknesses of recreational sampling strategies in context with three iconic species currently monitored by the DPI&F; snapper (*Pagrus auratus*), tailor (*Pomatomus saltatrix*) and Spanish mackerel (*Scomberomorus commerson*).

Towards better collection of socio-economic data for Queensland inshore fishery stakeholders

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Fisheries researchers and managers are well aware of the need to collect baseline biological data prior to a management change and to monitor biological indicators over time. However, such information for the socio-economic status of fisheries is rarely collected. This trend is changing, however, with the collection this year of baseline socio-economic data for inshore commercial, charter and recreational fishers and seafood consumers on Queensland's east coast prior to the implementation of the Queensland East Coast Inshore Finfish Management Plan. Information on preferred fishing methods, areas and target species, and social information including fishers' and consumers' expectations and satisfaction levels has been collected. In addition, these surveys explore stakeholders' opinions regarding the current inshore fisheries management system and the need for, implementation of, and expected effects of, management change. Available baseline data will allow effects of management

changes on all fishery users to be easily measured. Documenting any negative impacts of management change on stakeholders may help minimise such impacts in the future. These baseline surveys also mark the start of the development of a long-term socio-economic monitoring system based on socio-economic indicators. Socio-economic indicators may be useful to measure impacts of both management and environmental change. Importantly, changes in socio-economic indicators over time may highlight environmental changes before changes in biological indicators are detected.

Identifying shark fins in New South Wales: cost effective methods for fisheries management and enforcement

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Increasing human demand for shark fins poses a major threat to shark populations worldwide. Over recent years, a burgeoning trade in illegally caught fins has been fuelled by modern transportation and refrigeration technologies, which exploit the social pressure of cultural traditions. In response to this issue, the measures outlined by a United Nations International Plan of Action have been incorporated into a National Plan of Action for the Conservation and management of Sharks. Under this plan State and Territory fisheries agencies are required to assess regulations pertaining to fining.

At present in NSW, sharks are targeted in the Ocean Trap and Line Fishery and caught as by-catch in the Ocean Trawl Fishery. While it is illegal to remove fins from a shark and discard the torso at sea, sharks may be gutted and returned to shore for processing (including the removal and sale of fins). Unfortunately, in the instance of illegal fishing activities, no attempt is made to identify the species of shark from which the fins were removed. As a result, possible offences concerning two threatened species (grey nurse and great white sharks), may be overlooked. Additionally, the misreporting of shark catches may affect fisheries stock assessments.

The aim of this project is to develop cost-effective methods of identifying shark fins confiscated from fishing vessels. The project will explore the potential of using several different techniques to identify shark fins including colour, photo-morphology, electron micrograph and the use of a hand lens to differentiate denticle shape and density.

Monitoring Queensland's mud crabs

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Mud crabs, *Scylla serrata*, are a highly desired species utilized by commercial, recreational and indigenous sectors along the entire Queensland coast. Since 1999, the Queensland Department of Primary Industries and Fisheries (DPI&F) have monitored mud crab populations through annual surveys in various river systems around the Queensland coastline. In 2005–06 the DPI&F conducted a comprehensive review of it's mud crab monitoring program. The review aimed to reassess the program objectives to ensure the data being collected were appropriate to monitor mud crab stocks in Queensland. The review enabled DPI&F to assess whether the 17 sites monitored were still appropriate and reflected regions of high harvest and regions in close vicinity to a large resident population. This presentation will demonstrate some of the key factors leading to the review, data used to assess our objectives and the changes to the program as a result of the review.

Using hook/bait size and angling technique manipulations to influence the catch, hooking location and initial post-release survival of recreationally caught black bream (*Acanthopagrus butcheri*)

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Post-release survival of line-caught black bream (*Acanthopagrus butcheri*) and numerous other species is strongly influenced by hooking location. Maximising post-release survival rates for *A. butcheri* is reliant upon anglers increasing shallow-hooking rates. The present study followed from previous studies by the authors and aimed to determine whether higher initial post-release survival rates (survival for first hour) are achievable by increasing hook/bait size (sizes 8, 4 and 1 hooks tested) and fishing with tight instead of slack lines. Shallow-hooking increased when larger hook/bait sizes and tight line fishing were used, and consequently initial survival increased. Survival was not directly affected by hook size, but was higher for deep-hooked fish that did not have the hook removed. Post-mortem examinations showed that removing hooks from deep-hooked fish caused more frequent and severe throat and gill injuries, which resulted in mortality. This study demonstrated that *A. butcheri* initial post-release survival

increases when anglers use larger hooks and do not remove deeply engulfed hooks. The methods used in this experiment were innovative because; the short (≤1 hour) holding time was directly based on and comparable to previous literature; experimental weaknesses associated with not using control fish were mitigated by comparing the survival rate change rather than determining reliable point estimates; post-mortem examinations provided valuable corrections to anglers' records of hooking locations; these methods nullified much of the financial, logistical and conceptual (wild fish held in captivity) constraints of obtaining and holding control fish as in most scientifically rigorous post-release survival research.

Spatial differences in size of maturity and relative reproductive potential of southern rock lobster (*Jasus edwardsii*) in South Australia: implications for management

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The annual commercial catch from the Southern Zone of the South Australian rock lobster (*Jasus edwardsii*) fishery is ~1,900 tonnes, representing ~50% of total landings from southeast Australia. Size at onset of maturity (SOM) and relative reproductive potential (RRP) of female rock lobsters were compared between northern and southern regions as well as between inshore and offshore sites, with a view to providing a basis for future fine-scale spatial management of the resource. SOM, estimated as the size at which 50% of females reached sexual maturity (L50) was higher in the northern sites compared to southern In addition, SOM was notably higher within inshore sites compared to offshore grounds. Approximately 20% of lobsters above the MLS in the commercial catch in the northern areas were under the L50 estimate. RRP, as a measure of egg production, was calculated for each size class from the product of fecundity, SOM and population length frequency. Only 6% of RRP was contributed by female rock lobsters below the Minimum Legal Size (MLS) in the north, compared to 34% in the south. Similar regional differences in RRP size classes were observed between inshore and offshore grounds. Given that a single MLS of 98.5 mm carapace length exists across the entire zone, regional differences in SOM and RRP in the fishery suggest that different MLSs may be beneficial, particularly if the fishery is to be effectively managed at finer spatial scales.

The life histories and behaviour of *Notolabrus gymnogenis* and *Ophthalmolepis lineolatus* (Teleostei: Labridae): implications for their management.

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The life histories and behaviour of *Ophthalmolepis lineolatus* and *Notolabrus gymnogenis* were investigated in temperate waters of south-eastern Australia to provide information for the effective management of these commonly captured species. Both species exhibited the typical labrid reproductive strategy of protogynous hermaphroditism. Juveniles sexually matured into initial phase females at ca 184 mm total length (TL) (2.0 years) before changing sex into terminal phase males at ca 295 mm TL (5.2 years) in *O. lineolatus* and ca 273 mm TL (4.5 years) in *N. gymnogenis*. However, variable lengths (ages) at sex change suggest social interactions may influence the timing of sex change. Timing of reproduction was asynchronous among species with reproductive activity peaking in mid summer to early autumn (January-March) in *O. lineolatus* and late autumn to mid spring (April-Oct) in *N. gymnogenis.* Sectioned otoliths were used to determine that *O. lineolatus* and *N. gymnogenis* were fast growing to the lengths (ages) of ca 300 mm TL (6 years) with longevity to at least 13.8 and 9.6, respectively. In contrast to *O. lineolatus* which were home ranging, behavioural observations revealed that male *N. gymnogenis* aggressively defend reef patches of approximately 600 m^2 for at least 2 years. Up to 12 juvenile and female individuals share these reef patches. Frequently fished populations of *N. gymnogenis* are therefore likely to experience significant disruptions to their social organisation and are at great risk of overexploitation as territoriality limits the density of reproductive males on rocky reefs.

Understanding the biology of the Long-finned Gurnard: a step in developing ecosystem based fisheries management for the NSW Ocean Prawn Trawl Fishery

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Ecosystem based fisheries management recognizes the need to understand the effects that a fishery may have on all species, not just the targeted retained species. Whilst several studies have examined the biology and ecology of key species taken in the NSW Ocean Prawn Trawl

Fishery, very little is known about many of the secondary, non-target species. The aim of this study was to obtain biological information on the long-finned gurnard, *Lepidotrigla argus*, which is a major component of the discarded by-catch in the NSW Ocean Prawn Trawl Fishery. Age, growth and reproduction of the long-finned gurnard were assessed, with samples collected during a depth-stratified trawl survey of fishing grounds off the Clarence River between April 2006 to October 2007. The estimated maximum age of *L. argus* was 5+ and 6+ years using whole oil immersed otoliths and electronic length frequency analysis (ELEFAN), respectively. The mean length at maturity (L_{50}) was 13.1cm for females and 13.5cm for males. Gonadosomatic Index and macroscopic staging of gonads indicated that long-finned gurnards were reproductively active year-round, however there was evidence of periodic recruitment into the population. Length frequency distributions indicate that juveniles recruit into shallow nursery areas at 30-60m depths and migrate into deeper waters at 60-90m depths when mature. The age, growth and reproductive information obtained for this major by-catch species is one of the first steps in understanding the impacts of fisheries at an ecosystem level.

Recreational fishing regulations for Murray crayfish, are changes required to ensure the sustainability of this icon species?

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Over the past century, Murray Crayfish (*Euastacus armatus*) has declined in abundance and distribution across the Murray-Darling Basin. One of the main threats to this iconic species is thought to be over-exploitation by the recreational fishery. However, the magnitude and nature of this impact is largely unknown. To address this potential threat, fishing regulations governing the time of year, number, sex and size of individuals that can be removed have been in place in Victoria and New South Wales since 1989. However, continuing declining numbers of Murray crayfish brings in to question the effectiveness of these fishing regulations, the validity of the knowledge that underpins them and the extent of compliance by fishers. Here I present an overview from my PhD project that aims to address these knowledge gaps through the use of interviews (fisher, scientist and fishery managers), workshops, field work, laboratory experiments and population modelling. Preliminary results from the fisher interviews and a field study examining the difference in Murray crayfish sex ratios and population structures between fished versus non fished areas will be presented. Knowledge generated by this project will be used to aid the development of a model to support effective, socially acceptable fishing regulations for Murray crayfish.

Estuary perch: learning more about this southern enigmatic sports fish

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Estuary perch is a catadromous fish endemic to the coastal rivers and lakes of south eastern Australia. Very little is known about this species and is often considered an incidental bycatch within the recreational fishery. Recently, however, technological advances in fishing equipment has led to sports fishers increasingly targeting estuary perch, with many fish being released following capture. An overview is provided on the PhD research being done on the lesser known aspects of the species' biology, life history and ecology. Estuary perch are a relatively long lived fish found in the upper estuarine areas and migrate to spawn in the lower reaches of rivers in winter and early spring. At other times they move both upstream and downstream in estuaries, often in relation to river discharge and salinity levels. The results of this research will provide advice for sustainable management of this recreationally important native species.

A new approach for managing the data, information and knowledge associated with the resource assessment of multi-species fisheries

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The reporting obligations associated with environmental assessment of fisheries require significantly improved systems to manage and report upon fisheries data. However, it is not just "the data" that needs better systems, but also the analyses, results, inferences and conclusions associated with those data. Traditionally, most of these subsequent analyses are completed in spreadsheet applications such as Excel, published in word processors such as Word, and then distributed as proprietary binary files.

The lack of any standardization within this process will lead to the fragmentation of algorithms, data and information which can compromise reporting on larger systems (such as intranets and the internet). Furthermore, the inclusion of both data and algorithms into a single file (as in Excel) is recognized to be poor systems design. We propose a new approach that uses a combination of W3C standards, XML and the open-source R statistical package. Our system uses the R software system to execute a component of an assessment (for example, plotting a catch time series, or fitting a growth curve). The R XML library is used to read and write information from and to structured XML files. We then use the XSLT language to transform the XML data for multiple purposes including HTML-based web pages, or the text and statistical information presented in reports.

Examples will be given of how this generic approach can be used to undertake a wide range fishery analyses. Additional examples will be provided of how these analyses can be combined using web design tools and other scripting languages to manage the data, information and knowledge associated with contemporary multi-species fisheries.

Stock assessment of the Australian East Coast Spanish mackerel fishery

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The East Coast Spanish Mackerel Fishery (ECSMF) is a line fishery targeting the largest of the mackerel species in Queensland – *Scomberomorus commerson*. Spanish mackerel are highly sought after by both commercial and recreational fishers, and combined these sectors have a commercial worth of $7-14 million dollars at wharf.

The ECSMF stock has long been considered to be heavily exploited, but until recently data paucity has prevented a comprehensive assessment. There has been particular concern over, and interest in explaining, the last three years of total commercial catch which have been significantly depressed. Here we report that the stock biomass is likely around the level at which maximum sustainably yield (MSY) occurs, with biomass levels in 2007 being between 30%-50% of virgin biomass. The weight of the evidence points towards the recent three-year trend being predominantly due to flow-on consequences of management changes and other external factors (for example rising fuel costs), rather than lower biomass.

In order to integrate catch, length composition and age composition data, this assessment used a Bayesian approach with posterior probability distributions estimated by a Markov Chain Monte Carlo (MCMC) algorithm. Recruitment anomalies ('process error') were also estimated using MCMC. A non-standard parameterisation of the model was included in the assessment that allowed MSY and harvest-rate-at-MSY to be estimated directly from the data. These techniques and their importance for the assessment are explained in non-technical language.

A preliminary consideration of bycatch issues in South Australia's most complex fishery

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Australian fisheries should be managed according to the principles of ecologically sustainable development requiring an integrated approach that considers impacts on target species, bycatch and by-product species, and habitats. The Commonwealth Department of Environment, Water, Heritage and the Arts (DEWHA) is responsible for assessing whether fisheries conform to the requirements of the EPBC Act (1999). In 2005 an ecological

assessment for the Marine Scalefish fishery of South Australia was prepared for consideration by DEWHA. This complex, multi-species, multi-gear, multi-sector fishery operates throughout all of the State's coastal waters. DEWHA concluded that the fishery did have a 'sound' management framework but there were some risks to be managed, including 'the absence of an on-going monitoring system for the bycatch from each sector of the fishery'. It recommended that a system be developed and implemented for quantitative monitoring of bycatch sufficient to identify changes in its composition and the quantity of bycatch taken in each sector of the fishery.

To implement such a system would be daunting for this relatively low-value fishery given its complexity, the geographic scale and temporal variability. Consequently, a preliminary study was undertaken to determine the nature, types and scale of bycatch taken in the fishery. The project scope was purposely constrained to the commercial fishing activity and its three main gear types, i.e. handlines, longlines and haul nets, in the gulf region of the State. The study utilized scientific observers on board commercial fishing vessels. The findings of the study, with respect to establishing an efficient long-term monitoring program, are considered.

An ecosystem study of the eastern tuna and billfish fishery

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The Eastern Tuna and Billfish fishery (ETBF) is a major commonwealth fishery off eastern Australia. It is a multi-species fishery targeting swordfish, yellowfin and bigeye tuna, striped marlin and albacore as well as capturing a number of bycatch species. The fishery is managed on a species-by-species basis in terms of catch allocation, however, the effects of fishing one of these species on other components of the ecosystem are largely unknown. With the requirement to move to ecosystem based management (EPBC Act 2001), this understanding is particularly relevant. We have recently completed a study of the biological oceanography of the region and feeding ecology of the major fish predators to provide the information needed to construct qualitative and quantitative models of the ETBF ecosystem. These models will be used to investigate scenarios of impacts of fishing and future climate change. In particular, quantitative models require accurate inputs from all levels of the ecosystem if these scenarios are to be robust. Here we present some of the results of the biology of the region with an emphasis on estimates of potential prey biomass, food web pathways and resource partitioning in relation to the regional oceanography.

Ecological effects of longlining and climate change on the pelagic ecosystem off eastern Australia

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Australia's Eastern Tuna and Billfish Fishery (ETBF) is a large multi-species fishery that targets apex predators thought to exert 'top-down' control of pelagic ecosystems. An ecosystem model was constructed to explore the ecological effects of longlining and climate change from 1998 to 2018. A 50% reduction in fishing effort resulted in only modest (2-20%) increases in the biomass of target species. Doubling the fishing mortality on target species (simulating alternative harvest strategies) also resulted in <20% changes in the biomasses of any functional group. However, removal of all sharks resulted in 100-200% increases in the biomass of turtles, yellowfin tuna and albacore, and 10-40% declines in wahoo, dolphinfish and striped marlin. Climate change scenarios involving modifying the biomass of micronekton fishes and squid resulted in trophic cascades, highlighting their importance as key prey groups in the system. Our results suggest there are no 'keystone' predators among high trophic levels since they share a diverse prey base and collectively only represent <1% of the total system biomass. Consequently, the removal of a single apex predator group is rapidly compensated by small changes in the biomasses of several competing groups within the same trophic level. However, when biomass is altered in groups having high biomass and production rates (P/B) that serve as important prey and predators, more dramatic cascading effects occur throughout the system. We advocate that these species may contribute to 'wasp-waist' control of pelagic ecosystem rather than strictly top-down or bottom-up control that reputedly drive other pelagic systems.

POSTER PROGRAM

Catch-and-release: estimating and maximising the survival of released angler-caught fish

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Since 2003, the NSW Department of Primary Industries (with funding from the Recreational Fishing Trust) has been undertaking research to estimate and maximise the survival of released angler-caught fish. The work involves a series of experiments in the field (as part of recreational fishing events) and aquaria that aim to (i) estimate the mortality and main contributing factors for key saltwater and freshwater species associated with local angling-and-release practices, and then if required, (ii) develop and test changes to gears or handling practices that maximise survival. So far, we have estimated the short-term (< 10 days) post-release mortality of snapper, *Pagrus auratus* (8 - 33%); silver trevally, *Pseudocaranx dentex* (2 - 37%); mulloway, *Argyrosomus hololepidotus* (19 - 27%); sand whiting, *Sillago ciliata* (7%); yellowfin bream, *Acanthopagrus australis* (3 - 28%); dusky flathead, *Platycephalus fuscu*s (4 - 9%); eastern sea garfish, *Hypohamphus australis* (49%); tailor, *Pomatomus saltatrix* (8%); Australian bass, *Macquaria novemaculeata* (0 - 8%); golden perch, *Macquaria ambigua* (0 - 27%) and Murray cod, *Maccullochella peelii* (15%). For many of these fish, the main factors contributing towards mortalities and/or other sub-lethal impacts have been isolated and subsequent recommendations made to improve survival. These various procedures are encapsulated in the following eight general handling practices:

1. Don’t target fish during their spawning.
2. Select the right rig.
3. Minimise hook damage.
4. Remove mouth hooks.
5. Cut the line on hook-ingested fish.
6. Avoid excessive handling of fish.
7. Minimise air exposure.
8. Keep the life in live-wells by selecting the correct design.

Simply following these recommendations has the potential to greatly increase the number of fish surviving after release and, ultimately, contribute towards the sustainability of recreational fishing in NSW.

Trawling in south-eastern Australian waters – key threatening process assessment

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The Threatened Species Scientific Committee (TSSC) assesses which threatened species and which key threatening processes should be listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). A Key Threatening Process is defined as a process that threatens or may threaten the survival, abundance or evolutionary development of a native species or ecological community (for example, injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris).

The TSSC is currently assessing whether "Damage to marine ecosystems by trawling in the area of the Southern and Eastern Scalefish and Shark Fishery (SESSF)" should be considered a Key Threatening Process. As part of its assessment, the TSSC will specifically consider whether overfishing, lack of refugia and damage to benthic habitat caused by demersal trawling is causing decline in marine species.

This poster will outline the steps taken to date in the assessment of the impact of demersal trawling in the SESSF, as well as discussing the individual marine species nominations that the TSSC will be assessing over the next twelve months. In particular, it will identify the steps in the assessment process where the marine science community will be invited to provide input.

Using CT scans to explore the effects of barotrauma on fish

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Depletion and over-harvesting of marine fish by commercial and recreational harvesters is a problem throughout the world. Fishery managers often require caught fish to be released after capture, with the intention of protecting vulnerable life stages or reducing harvest. However, most deep-water marine fish suffer from decompression trauma during capture and many do not survive after capture despite being released. In Australia, snapper (*Pagrus auratus*), and mulloway (*Argyrosomus japonicus*) are both valuable commercial and recreational species that exhibit signs of decompression trauma upon release. We are determining the effects of barotrauma (decompression trauma) on these species by using X-ray computerised tomography, known as CT scans, to look at physical abnormalities caused by the rapid reduction in pressure as fish are brought to the surface from depth. We are also testing basic reflex behaviours of decompressed fish to compare behavioural impairment with physical abnormalities. Preliminary results show differences in barotrauma symptoms among fish caught at different depths.

A framework for developing appropriate sampling tools for designing large-scale and long-term research surveys

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A prerequisite for undertaking large-scale and long-term research surveys should be the development of sampling gears and designs that are standardised, representative, optimal with respect to the quantity and structure of catch obtained and replicated over appropriate spatial and temporal scales. We present a framework for doing this preliminary research using pilot experimental studies. This involves: (1) identifying suitable sampling gears for the target species, (2) testing different configurations of gear and sampling practices to ensure that samples are representative, optimal and cost-efficient, (3) understanding spatial and temporal scales of variability across different strata, (4) cost-benefit analyses to determine optimal levels of replication. Examples of the strategy are provided from studies on fish assemblages in coastal lakes in south-eastern Australia and the general applicability and utility of the framework is demonstrated.

Surviving a sea-change: apparent survival of southern rock lobster (*Jasus edwardsii*) translocated to areas of higher productivity

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A novel management strategy to increase yield and value of the Southern rock lobster *Jasus edwardsii* fishery involves translocation of lobsters from areas with high abundance but slow growth rates into regions where they grow faster and develop better market traits. The survival of rock lobster following release has the potential to significantly affect the viability of translocation. The release site was surveyed approximately every 1-3 months for a period of 2 years after release of 2000 *J. edwardsii,* and apparent survival of translocated lobsters was compared to resident lobsters, using Cormack-Jolly-Seber modelling on mark–recapture data. Apparent survival did not differ between small and large residents, male and female residents, and male and female translocated *J. edwardsii*. There were small differences in survival between resident and translocated lobsters, with monthly survival estimates of small female resident lobsters 92.7% $\pm$ 1.1 SE compared to translocated females (all small) 87.9 % $\pm$ 1.2 SE, and survival in small male residents was 97.8 % $\pm$ 0.7 SE compared to 94.5 % $\pm$ 1.1 SE in translocated males. In both cases the lower apparent survival was chronic over the course of the experiment, rather than an acute period of mortality around release. Losses of lobsters through release mortality appear to be low and unlikely to significantly influence the feasibility of sea-ranching as a tool to enhance yield and value of the fishery.

Recreational catch and effort in a unique land-based pelagic gamefish fishery in south-eastern Australia

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Obtaining reliable catch estimates from the recreational sector is challenging, but vital for assessing the long-term sustainability of target species, and to assist in resource allocation for species shared by commercial and recreational sectors. The coastline of southeastern Australia is one of the few places in the world where anglers catch large game fish (e.g. marlin and tunas) from the land. This is the first study of this highly unique recreational land-based gamefish (LBG) fishery, which has existed since at least the early 1970s. Off-site logbook survey and opportunistic on-site roving creel survey methodologies were used to collect information over a two-year period on species and size composition of the catch, duration of trips, frequency of fishing and expenditure. A total of 27 taxa were recorded in diaries and on-site surveys. The most abundant species caught were yellowtail scad, blue mackerel and eastern sea garfish, which were used by anglers as live bait for larger target species. The most abundant species caught that were nominated as target species by anglers were longtail tuna, yellowtail kingfish, cobia and black marlin. Catch rates of these target species were low (0.05-0.13 fish hr^{-1}), but comparable to catch rates of similar species targeted by boat-based anglers. Preliminary estimates of the total catch of each species by LBG anglers indicate they generally account for only a small proportion of the total recreational catch of most species. However, they probably account for a large majority of recreational catches of longtail tuna in the region. Although this preliminary study provided important first order estimates of catch and effort, further on-site and off-site sampling and a stratified population survey to better understand participation rates is required to provide more robust estimates of the total catch.

Conservation genetics of commercially exploited sharks

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The proposition that low genetic variation increases the risk of factors such as disease and developmental instabilities has had little consideration in the marine environment. Commercial exploitation has lead to declines in shark numbers worldwide. While improved management has seen partial recovery of previously overfished species, such as gummy, *Mustelus antarcticus* and school shark, *Galeorhinus galeus,* it is unclear how past overexploitation has affected the genetic diversity and subsequent fitness potential of these populations. In this study we assess genetic structure and diversity in gummy and school shark. We will first characterize the population structure

of these two species and establish whether there are differences in genetic variation among regions. *A priori* we expect that low genetic variation will be present in some localities where populations have suffered significant declines. The relationship between disease/developmental instability and genetic variation will be investigated by collecting data on the presence and abundance of particular pathogens such as myxosporean parasites and investigating the occurrence of fluctuating asymmetry (a measure of random deviations from symmetry of bilateral traits and a common indicator of developmental stability). Finally, mating strategies will be determined as these influence effective population size, and therefore the rate at which we might expect genetic variation to be eroded. The outcomes of this study will have important implications for the future management of gummy and school shark as well as shaping our understanding of how shark populations respond to overfishing in terms of loss of genetic diversity and the repercussions of this loss.

Geographic variation in reproductive traits of the western king prawn (*Penaeus (Melicertus) latisulcatus* Kishinouye, 1896)

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The western king prawn, *Penaeus (Melicertus) latisulcatus*, is widely distributed throughout coastal waters of the Indo-west Pacific and is an economically important species across its range. It is predominantly a tropical species that exists at its latitudinal (and temperature) limit in South Australia's unique gulf systems the Spencer Gulf and Gulf St Vincent. Serial spawning occurs throughout the year in its Indo-Pacific range, but only seasonally during the summer months in South Australia. The fisheries management approaches of *P. latisulcatus* are therefore different across its distribution and comprehensive knowledge of its reproductive patterns are particularly essential in South Australia to ensure the sustainability of these fisheries.

This research examines the reproductive biology and ecology of *P. latisulcatus* in the South Australian Gulfs. We examine how fundamental reproductive traits (size at maturity, fecundity and maternal investment) of *P. latisulcatus* differ in relation to the ecological parameters compared to its tropical counterparts. In addition analysis of size-frequency data and other population parameters of *P. latisulcatus* in South Australia's Gulfs will be used to improve fisheries management practices aimed at ensuring the sustainability of these important commercial fisheries.

Potentially pathogenic parasites for sea-cage aquaculture of Australian fin fishes

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Metazoan parasites may threaten the sustainability and profitability of some fish species in the Australian fin fish aquaculture industry. In the sea-cage environment, farmed stocks can acquire infections from local populations of wild fish. The natural occurrence of wild fish near sea-cage farms provides an opportunity for parasite transfer between wild and farmed populations. However, the parasite assemblages of most wild fish species and the potential risk of these parasites to sea-cage aquaculture are largely unknown.

We have chosen 12 key native fish species to undertake a parasite survey in southern Australia including recreational species that associate with sea-cages, candidate species for aquaculture and currently farmed species,. We have recovered a range of parasite species, but have concentrated our work on copepods, monogeneans and digeneans because some species in these groups have been associated with pathology, morbidity or mortality in fin fish aquaculture. In this presentation, I will briefly report on three separate case studies (a copepod, a monogenean and a digenean species) from important fish species.

Observer-based research into commercial line fishing in NSW waters

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A range of line-fishing methods is used to commercially catch finfish in NSW coastal and continental shelf waters. These methods include handline, setline, trotline and dropline, and are part of the Ocean Trap and Line fishery, one of the nine fisheries managed by New South Wales Department of Primary Industries (NSW DPI). In 2007, NSW DPI began a two-year observer-based research program to collect detailed operational information about those four line-fishing methods, along with data regarding the species and sizes of finfish being retained or discarded following capture. Biological samples from retained sharks are also being taken where possible with a view to improving our knowledge and understanding of the biology of many of the shark species that inhabit NSW waters. Collectively, the information being gathered via the commercial line-fishing observer program will fill the many of the current gaps in documented knowledge regarding those fishing methods – particularly relating to any discarding of unwanted organisms (or 'bycatch'). Such knowledge is vital with respect to the effective management of such a diverse and complex fishery to ensure the sustainability of fisheries resources in NSW for future generations.

Spatial variation in parasites of king threadfin (*Polydactylus macrochir*) and blue threadfin (*Eleutheronema tetradactylum*) in Australian waters; implications for fisheries

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The use of parasites as natural markers continues to be an informative, cost effective method of determining stock structure and movements of commercially exploited fish species. Here we use permanent parasites to discern the stock structure of two commercially and recreationally important coastal fish; king and blue threadfin (*Polydactylus macrochir* and *Eleutheronema tetradactylum*) across their Australian distribution. Univariate and multivariate analyses of parasite abundance from fish collected from 4 primary fishing areas suggest the occurrence of multiple stocks of both species across northern Australia. The spatial relationships evident in this study suggest little mixing of fish between state jurisdictions, with further sample sites required to discern the fine scale stock structure across both species' distribution.

Optimising the stocking density of Australian bass: Estimating carrying-capacity in freshwater impoundments

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There is a need for reliable ecological models for optimising the stocking of fish in Australian freshwaters. The 'optimal' stocking density maximises the contribution of fish to a fishery and occurs at a fishery's carrying-capacity. We aim to optimise the stocking of Australian bass (*Macquaria novemaculeata*) in freshwater impoundments in SE Australia, using three complimentary approaches:

1. We will use ideal free distribution theory to estimate carrying-capacity by observing the rates of dispersal (also termed 'self-thinning') of stocked fish. We will stock patches of various habitat types with a range of densities of bass and observe and electronically-track their rates and magnitudes of movement. This will be replicated within and between impoundments.

2. We will use a general numerical predator-prey model based on the energetic needs of bass and their prey's availability to estimate the optimal stocking density and predatory impact of stocked bass in select impoundments. The model incorporates published models, life-history parameters, and size-specific growth and diet data, and a spatial component, based on the spatial distribution of bass (elucidated in part 1.) and the distribution of their essential habitat.

3. We will stock bass in custom enclosures in impoundments at a range of densities in a factorial, replicated design, to estimate each impoundment's carrying-capacity. Over-stocking will force density-dependent limitations, measured by decreased growth and/or survival of bass. So, by measuring the growth and survival of bass at treatment densities, we will converge on each impoundment's optimal stocking density. These densities will be compared with the modelled estimates from our predictive stocking model.

An overview of routine fisheries monitoring activities carried out by (or for) DPI&F in Queensland

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Queensland has a diverse range of commercially, socially and culturally valuable fisheries located throughout its coastal waters. There has been a significant commitment in recent years to establishing best practice management arrangements to ensure, among other objectives, long-term sustainability of these fisheries. This commitment has resulted in the need to improve assessment strategies, including developing performance measurement systems that incorporate routine assessments of target and non-target species and components of the ecosystem.

A variety of complementary monitoring programs have been developed and refined to collect the data required to calculate performance measures. Compulsory logbooks for commercial fishers have been the foundation of fisheries monitoring in Queensland since 1988. Periodic phone and diary surveys have collected similar information from recreational fishers throughout the state several times since 1997. Bus route creel surveys have been carried out in south east Queensland since September 2007. Routine monitoring programs to collect important biological data from a wide range of species have been operating throughout the state for up to 9 years. An organised and outcome-driven fisheries observer program has been operating throughout the state since 2003. While most of the activities in these monitoring programs are carried out by DPI&F staff using core funding, some of the activities are carried out by other agencies or community groups. Wherever possible, information from a range of other sources, such as research projects, charter boat logbooks and fishing clubs are integrated with the routinely collected information to carry out thorough assessments of a large number of fisheries.

The reproductive biology of *Chromis hypsilepis* (Pomacentridae)

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Fishes, of the family Pomacentridae, utilize a great range of reproductive strategies. *Chromis hypsilepis* is a schooling planktivore that occurs on rocky reefs from northern New South Wales to northern Tasmania. During the summer breeding season, large numbers of *C. hypsilepis* migrate to spawning aggregation sites on a semi-lunar cycle. A reproductive strategy of aggregating, demersal spawning and paternal egg care is rare amongst teleosts. Parental care is done by the male *C. hypsilepis*, who guard eggs for 4.5 days. The age, growth and reproduction of two populations (Terrigal, Jervis Bay, 200 km apart) of *C. hypsilepis* were compared. Results will be presented on: the validation of annual formation of opaque zones in sagittal otoliths, age/length at sexual maturity, longevity, and von Bertalanffy growth parameters. The results of this study are a necessary component of understanding the unique reproductive strategy of *C. hypsilepis*.


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