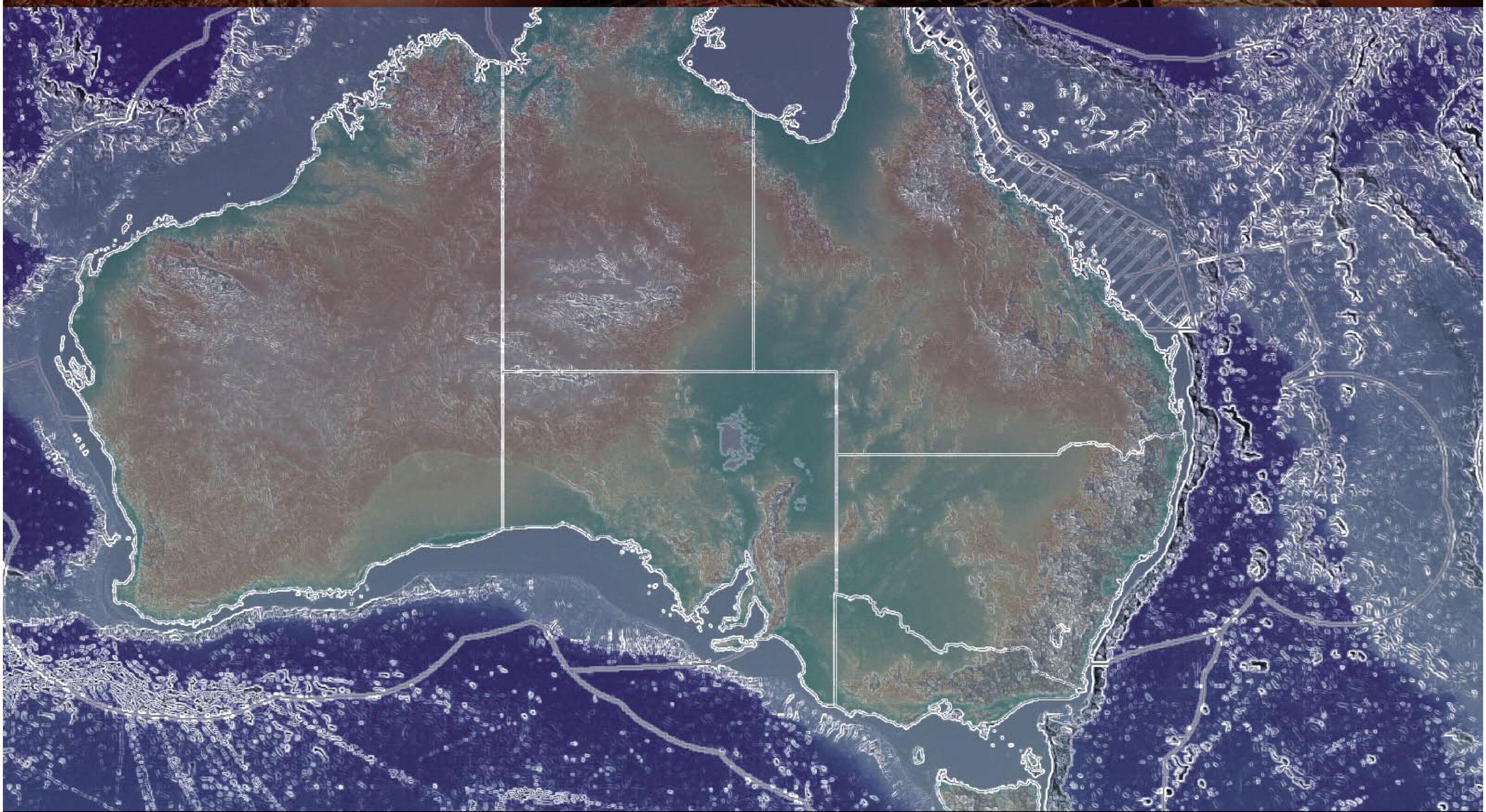
Australian Society for Fish Biology

2007 Workshop Proceedings

SPATIAL MANAGEMENT IN FISHERIES



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Workshop Overview

The 2007 ASFB Workshop was held at the National Academy of Science's Shine Dome in Canberra from 11-12 September 2007. The workshop explored the theme 'Spatial Management in Fisheries' and attracted 81 delegates, principally from Australia and New Zealand. The first day centred on discussing spatial strategies used specifically for fisheries management purposes and the second day examined the usefulness of Marine Protected Areas (i.e. no-take zones) as a management tool. During the final session of each day the keynote speakers formed a panel to discuss/workshop the issues raised.

The following general topics were discussed:

- The effectiveness of current spatial management practices in Australian marine and freshwater fisheries.
- The values of fishery dependant data for fine and broad scale spatial fisheries management.
- How to best design marine protected area networks from a fish biodiversity perspective.
- The need to find common ground between conflicting spatial requirements for biodiversity conservation and fishery sustainability purposes.
- Collaborative spatial data sharing and archiving.

The effectiveness of some spatial management tools, such as seasonal closures for known spawning sites, is well proven. However, the usefulness of other spatial management measures, such as creating permanent 'no-take' or refuge areas, is still open to considerable debate. The past decade has seen the increasing creation of marine protected areas (MPAs) and the like, particularly in Australian waters. Whereas such reserves are a promising tool for fisheries management (and biodiversity conservation), there are many questions about their effectiveness compared with conventional fishery management tools. Empirical evidence that marine reserves enhance fisheries yields is sparse.

The workshop noted the increased call for the widespread use of MPAs in response to the perceived failure of 'traditional' fisheries management, but concluded that the benefits to effective fisheries management from such area closures remain elusive and unquantified. Some spatial closures have arisen from strategic assessments of fisheries under the EPBC Act and it is probable that the fishing industry will be increasingly constrained to commercially productive areas. However, the major aim of Australia's MPA system is to protect biodiversity by establishing a network of representative areas. In freshwater, the establishment of riverine reserves in the Murray Darling Basin was shown to be complicated by the connectivity of river systems, flow regimes and widespread fish movement.

The workshop also stressed that MPA policy development is still running ahead of the scientific information and tools to support it. In many instances it is not clear what is being protected and what it is being protected from. A New Zealand study using environment-based statistical models to interpolate the distributions of 96 demersal fish species demonstrated the research needed to adequately define representative areas. Conversely, a case study of the recently established Batemans Marine Park in southern NSW found little scientific evidence to support the siting of no-take zones and claims that these would benefit fish populations. The workshop expressed concern at the biased selection of scientific information to justify the creation of these zones.

Recent years have seen an increasing focus on managing fisheries at finer spatial scales and the workshop agreed that spatial management is an important component of integrated management tools for successful fisheries. Case studies illustrated this fact.

Keynote Speakers

Dr David C Smith – CSIRO Marine and Atmospheric Research

Dr John Koehn – Arthur Rylah Institute for Environmental Research

Professor Colin Buxton – Tasmanian Aquaculture & Fisheries Institute

Dr Bill Phillips – Mainstream Environmental Services

Dr Nick Rayns – Australian Fisheries Management Authority

Dr John Leathwick – National Institute of Water & Atmospheric Research, NZ

Regina Magierowski – Australian Ocean Data Network

Professor Robert Kearney AM – University of Canberra

Spatial management in fisheries: the answer to our problems?

David C. Smith, Elizabeth A. Fulton, Anthony D.M. Smith, Ross Daley and Alan Williams
CSIRO Marine and Atmospheric Research, GPO Box 1538, Hobart, TAS 7001, Australia

Zoning and 'rights to access' have been a feature of fisheries since the earliest recorded civilizations. More recently, fisheries managers have used spatial management to various degrees, and virtually all management plans implicitly use some form of spatial management for a variety of purposes. Until recently the focus has been on target species and maximizing yields. However, there has been increasing community concern about the wider ecological impacts of fishing resulting in moves to ecosystem based fisheries management. Explicit spatial management (including closures) has also become a key requirement for a number of Australian fisheries arising from strategic assessments under the EPBC Act. There has also been an increasing focus of fisheries management at finer spatial scales. In addition, in response to a perceived failure of traditional fisheries management, there have been frequent calls for widespread use of MPAs (primarily no-take zones) as fisheries management tools.

In this paper we review the recent fisheries literature and show the increasingly explicit reference to spatial management in fisheries science. The Ecological Risk Assessment for the Effects of Fishing applied to demersal habitats and fisheries closures for upper slope gulper sharks demonstrate the important role that fishery spatial management has in mitigating fishery impacts. More generally, the results of a recently completed 'whole of fishery' MSE study demonstrate the importance of considering spatial management as one of an integrated set of management 'levers' for successful fisheries rather than as a 'panacea' to solve all fishery management issues.

Introduction

Zoning and 'rights to access' have been a feature of fisheries for millennia. Hammurabi (1792-1750 BC) used spatial management in the Babylonian empire (King 1900). In return for the duty of keeping the canals in order, which prevented flooding of shore-based industries as well as being a vital route for commerce, the villagers along the banks had the privilege of fishing the waters in the portion of the canal in their charge, and any poaching by other villagers was strictly forbidden. South Pacific Islanders have had reef tenure for centuries (Johannes 1978).

In more recent times, the governance arrangements for fisheries management are strongly based on the use of spatial structures and management measures, such as the boundaries of jurisdictions, management plans, and zoning of the kind and intensity of fishing. Spatial and temporal closures are also a common feature of current fisheries management. Ward *et al.* (2001) and Smith *et al*. (2004) provide examples of management and research respectively. Specifically fishery closures are commonly used to protect vulnerable life history stages such as nursery areas for juveniles and adult spawning aggregations. Habitat protection is also a common objective. Closures and zoning are also used for resource allocation, for example recreational fishing only zones or gear specific zones.

Despite this you could be forgiven for thinking that fisheries spatial management is new, and extensive closures (particularly MPAs?) will 'save' the world's fisheries. So what has changed? Fisheries science and management is under increasing scrutiny (Smith and Smith 2001). There are widely held views that fisheries management has been unsuccessful and there is concern for the status of fish stocks worldwide (Mace 1997). In response to a perceived failure of traditional fisheries management, there are increasingly frequent calls for the widespread use of MPAs (primarily no-take zones) as the key fisheries management tool.

In recent years fisheries management has shifted from a focus on target species and maximising yields to considering the wider ecological impacts of fishing and moves to ecosystem based management (EBFM) (Pikitch *et al.* 2004, Smith *et al.* 2007). In Australia, a number of policy directions have driven this change:

- National commitment to ecologically sustainable development (ESD) (1992)
- Australia's Oceans Policy (1998)
- New environmental legislation – Environment Protection and Biodiversity Conservation Act (EPBC) (1999)
- Adoption of EBFM as a policy goal (2006).

Explicit spatial management (including closures) has become a key requirement for a number of Australian fisheries arising from strategic assessments under the EPBC Act. This policy development ran ahead of the scientific tools and methods to support it, and still does (Smith *et al.* 2007). For example, while there is a broad understanding of the impacts of spatial management on target species, the implications of MPAs for the ecosystems that support fisheries is largely unknown (Smith *et al.* 2004).

Within the broad area comprising fisheries spatial management there are two relatively recent initiatives. First management at much finer spatial scales reflecting increased understanding of the spatial heterogeneity of many stocks (see for example Buxton *et al.* this volume) and second, the use of closures or zones to mitigate fishery impacts.

This paper comprises three distinct components. Two examples of the use of spatial management to mitigate fishery impacts are described; application of Ecological Risk Assessment (Smith *et al* 2006) to demersal habitats, and closures to protect gulper sharks (Squalidae) threatened by over-fishing in temperate offshore fisheries. The third discusses a recently completed project on a 'whole of fishery' management strategy evaluation (Fulton *et al.* 2007). The latter is particularly relevant because the project assessed a range of alternative management strategies that included varying degrees of spatial management.

First it is illuminating to look at how much fisheries science is directed towards answering questions regarding the spatial nature of fisheries resources. To this end an analysis of the number of papers in the recent fisheries scientific literature that pertain to spatial management is briefly described.

Spatial considerations and fisheries science

A literature review using the Aquatic Sciences and Fisheries Abstracts (ASFA) was undertaken. The descriptor for the search strategy was 'fishery management' or 'fisheries biology' and the key word was 'spatial'. It is clear from this that papers that have some reference to spatial issues within fisheries have increased enormously (Figure 1).

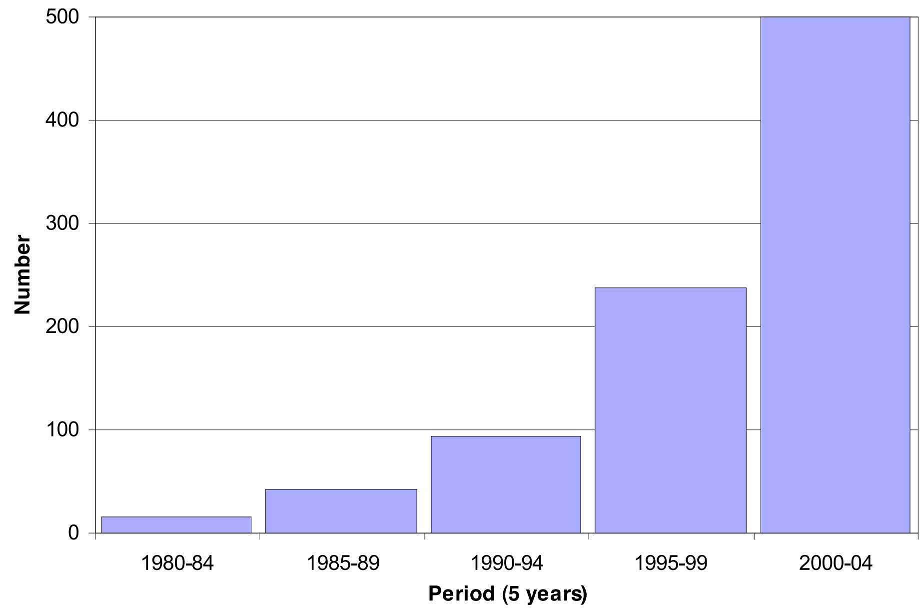

Figure 1: Number of 'fisheries management' publications in AFSA that used spatial as a key word.

From 1980-84 to 2000-04 the number of papers that contained or at the least identified with science that contributed to an understanding of spatiality in a fisheries context increased by over 20 times. During this period there was also an increase in the number of fisheries management or fisheries biology papers in ASFA. This however, was less than 3 times, from 2651 in 1980 to 7514 in 2000. This still means that there was over a 700% increase in the proportion of papers that addressed some spatial component during this period.

Journal abstracts for the period 2000-04 were reviewed and placed into categories based on the focus of the abstract (Figure 2). Papers (as determined by their abstracts) dealing primarily with spatial patterns (this includes population biology, distributions, fishery dynamics, etc) made up 35% of the total. Papers focussing on fishery closures, marine reserves or MPAs made up only 13% of the abstracts reviewed. Of these, 75% dealt explicitly with fisheries issues, 18% conservation and 7% socio-economic considerations. The general category includes papers dealing with everything from gear efficiency to ecosystem characterisation. Papers dealing specifically with social and economic issues were few (less than 1%).

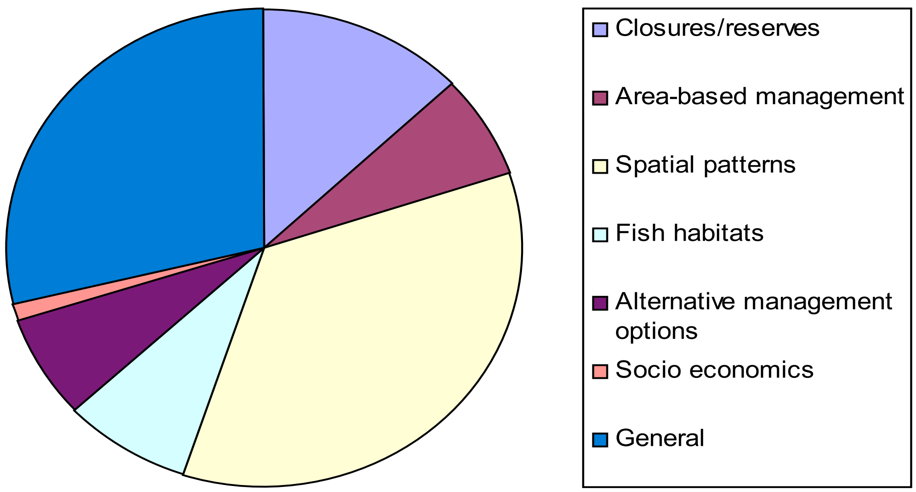

Figure 2: Categorisation of abstracts from ASFA, 2000-04. Search: fisheries management; key word spatial. n=425.

The results of this brief review were somewhat surprising. Despite the huge interest in MPAs in recent years and particularly the implications for fisheries management, papers dealing with fisheries closures or MPAs made up only 13% of the abstracts reviewed. Based on these abstracts it is also clear that terminology issues are yet to be resolved. In many, management objectives were not defined but it was assumed that MPAs were established to meet fishery objectives in some and conservation objectives in others. There was an increase in the number of papers in the fisheries literature with spatial as a key word. However, the greatest number dealt with more 'traditional' issues such as fishery dynamics, fish distributions, biology, habitats etc. This indicates a degree of 're-badging', perhaps not unexpected given the increasing focus on spatial management.

Mitigating fishery impacts

A method to mitigate impacts on habitats by assessing the risk of fishing impacts

CSIRO and AFMA have developed an ecological risk assessment using a common framework for assessing risk to species, habitats and communities: called Ecological Risk Assessment for the Effects of Fishing (ERAEF) (Smith *et al.* 2006). The approach is hierarchical with 3 primary levels that permit efficient screening of low risks, enabling resources to be prioritised to deal with higher risk levels.

In assessing risks to habitats, the 2nd level in the hierarchy involves a semi-quantitative Productivity Susceptibility Analysis (PSA) that evaluates the interactions between subfisheries (gear types) and the range of habitat types present within the fishery area (Hobday *et al.* 2006). This can be followed by a quantitative third level analysis to examine high risk interactions. At this stage other metrics for habitats are included, e.g. how much of any type occurs within a fishery area.

ERAEF was applied to 14 of the Australian Fishery Management Authority (AFMA) managed fisheries with 21 subfisheries that have some degree of benthic interaction. Habitats were defined as the seafloor structure and its attached invertebrate fauna with types assessed mainly from video survey data. Types were classified using substratum, geomorphology, and fauna within primary depth zones – the coastal margin (0-25 m), inner shelf (25-100 m), outer shelf (100-200 m), upper slope (200-700 m), and the mid slope (700-1500m).

The PSA is a semi quantitative, 2 dimensional analysis of benthic habitat, vulnerability posed by the direct impacts of capture fishing (Figure 3). It measures 'potential risk' because direct measures to determine 'absolute risk' - abundance or mortality rate - were generally not obtainable for habitat at a national scale. It builds on a vulnerability assessment in temperate SE Australian waters proposed by Bax and Williams (2001), where axes described a habitat's resistance (to physical modification) and resilience (the time taken for the habitat to recover to its original state once modified). In ERAEF a set of quantifiable attributes describe the intrinsic risk of a habitat to specific fishing gears as its 'susceptibility' and its resilience as its inherent 'productivity' (Hobday *et al.* 2006).

Susceptibility is broken down into 3 aspects – Availability, Encounterability, and Selectivity (each with its own set of attributes to measure risk) (Figure 3).

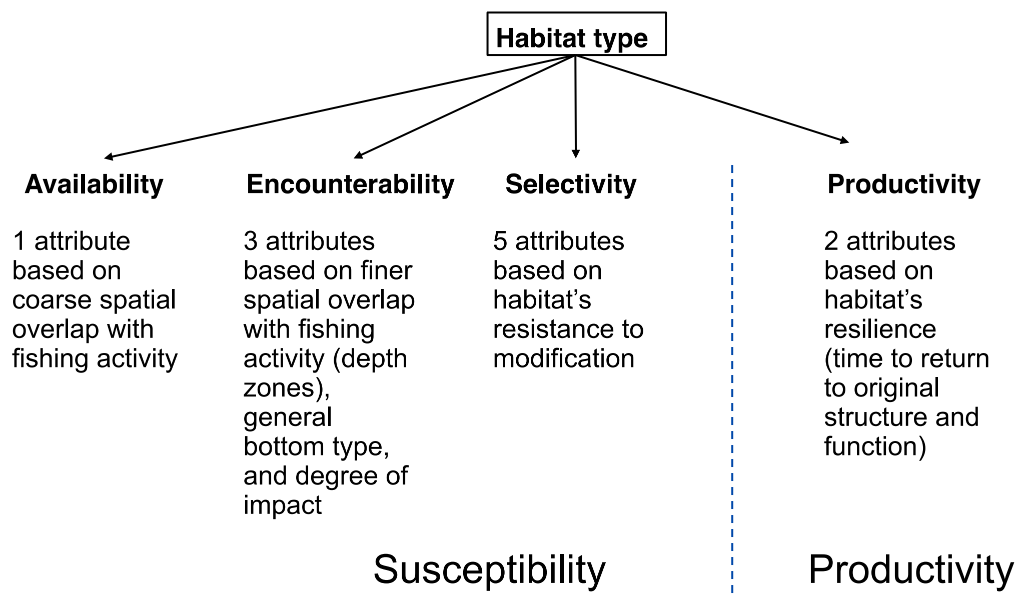

Figure 3: Ecological Risk Assessment for the Effects of Fishing: Habitat

Many other aspects of habitat productivity were considered but appeared correlated or not adequately quantifiable. Many just lacked information.

Attributes are populated by fishery specific data (GIS fishery areas and effort mapping); photographic data are used to characterise habitat types, and underlying some of the attributes, a set of explicit assumptions specifically dealing with productivity in different faunal groups and depths. Decision rules may take into account special consideration of features of conservation value, for instance canyons and seamounts, and relative regeneration times of the different faunal groups at depths greater than 200m (upper and mid slope depths). Lookup tables detail relative effects mainly of gear and depth, on faunal group, or fishery.

While attributes were generic to all sub fisheries, scores are unique to a subfishery capturing differences in fishing methods, regions and depths fished. Scoring of attributes included use of a 3 rank system: 3 - highest risk and greatest susceptibility; 2 - moderate risk and medium susceptibility; and 1- low risk or the least susceptible. The assumption underlying this simplified ranking recognises that there is a gradient of fishing impact between gear types and across habitats.

Availability, Encounterability and Selectivity risk scores are multiplied together (Smith *et al.* 2006). A low risk score for any aspect will result in a low overall susceptibility score but for a habitat with a very low productivity (i.e. mid slope types) a high overall risk score for vulnerability will still result when Productivity is taken into account. Productivity attributes are treated additively, therefore are not independent, and have the effect of significantly affecting final risk scores. Only attributes for which there were data were utilised. Application of this method has resulted in very low levels of uncertainty indicating that the approach can be widely applied (Hobday *et al.* 2006). In addition, a feedback loop, incorporating expert judgement, helps identify false positives and false negatives in the calculated risk levels.

The second level PSA analyses have informed fishery managers about potentially high risk interactions with habitats enabling responses to be considered and prioritised.

Gulper sharks

Three upper slope (300–600m) gulper shark species (Centrophoridae: *Centrophorus* spp) have been nominated for listing as threatened species under the EPBC Act: endeavour dogfish *C. moluccensis,* Harrissons dogfish *C. harrissoni* and southern dogfish *C. uyato*. They are long lived (45+ years), have a high age at maturity (15–30 years) and low fecundity (e.g. 2 pups each 3 years) (Fenton 2001, McLaughlin and Morrissey 2005,Whitely 2005). Based on research vessel ‘Kapala’ surveys it is estimated that the population size of gulper sharks in the mid 1990s was reduced to <1% after 20 years of trawling on the NSW upper slope (Graham *et al.* 2001).

Gulper sharks are taken in the Southern and Eastern Scalefish and Shark Fishery (SESSF) and by some State managed fisheries. Landed annual catches of up to 500 tonnes have been reported (Daley *et al.* 2002). Primarily taken by trawling, there was also a targeted fishery using gillnets off Victoria in the early 90s. Gulper sharks share the same depth and habitat as key target species ling and blue-eye and remnant populations are now affected as a bycatch of an expanding auto-line fishery (CSIRO 2005).

These sharks are broadly distributed on the upper slope and while a 30 kg trip limit is in place it is unlikely that this alone provides sufficient protection for the species. Post capture mortality is also high so released sharks are unlikely to survive. The estimated sustainable yield for gulper sharks is so close to zero that even as bycatch populations are unlikely to be sustained (Forrest and Daley 2007). In response to concerns about these species, the AFMA recently closed three areas to fishing (Figure 4): a 60 mile closure off Port Lincoln (to protect southern dogfish); a 30 mile closure off NSW (endeavour dogfish); and a 30 mile closure off north east Tasmania (Harissons dogfish).

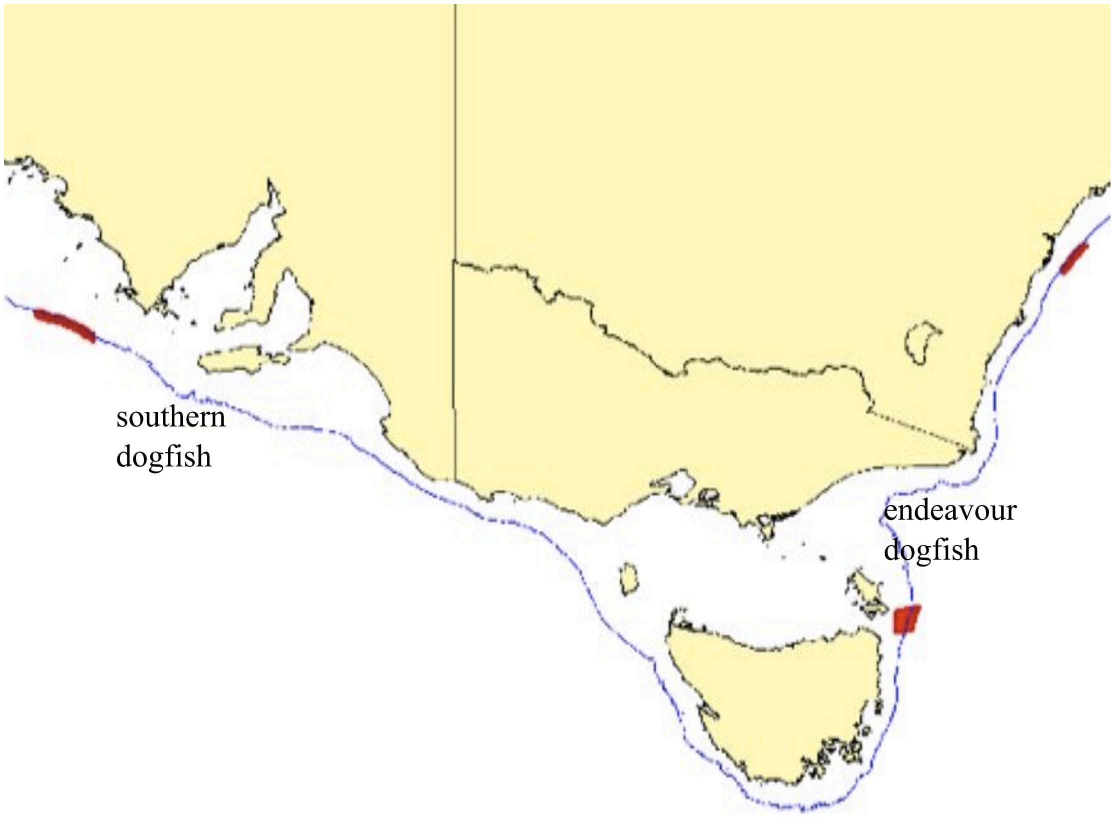

Figure 4: Gulper shark fishery closures and the species of interest.

The position and size of these closures was determined using the best information available at the time, including an industry survey of the Great Australian Bight (CSIRO 2005). However, there remains significant science questions:

- How many closures should there be, how big and where?
- Are the sharks resident within the closures or do they move in and out seasonally?
- What is the preferred habitat: 400m contour, canyons?
- How do gulpers utilise preferred habitat: cover, food/daily movements, breeding, and migration?
- What ecological processes facilitate habitat utilisation?
- Do we currently have the best area x time requirements for spatial management?
- How do we monitor and assess performance of these closures?

The methods needed to answer these questions include: non-lethal abundance measures; swath mapping bathymetry data; underwater camera systems to assess habitat usage; movement studies particularly using electronic tagging; and cage experiments and fishery observations on survivorship of tagged animals. Tagging methods will have to be developed for species taken at these depths.

The above is in no way intended to suggest the current closures should not have been implemented until the methods had been developed and the questions answered. Clearly urgent action was required. However, an adaptive approach can be taken to fisheries closures such that management action can be refined as more information is obtained.

'Whole of fisheries' MSE – evaluating the role of spatial management

The results of a recently completed project 'Evaluation of alternative management strategies for management of Commonwealth fisheries in southeastern Australia (Smith *et al.* 2004, Fulton *et al.* 2007) are briefly summarized here as they provide important insights into the role of spatial management in a broader fisheries context. EBFM is being widely adopted as a policy goal and, despite this shift in focus from 'traditional' fisheries management, the "levers" are still much the same: input controls, output controls, technical measures, spatial management (zones, closures etc).

The project applied a management strategy evaluation (MSE) approach (Punt *et al.* 2001) to assessing alternative management strategies for the Southern and Eastern Scalefish and Shark Fishery (SESSF) at the 'whole of fishery' level. The SESSF is a complex 'multi-everything' fishery (Smith and Smith 2001). It is a combination of previously separate fisheries including trawl and Danish seine, shark gillnet and line fisheries. It is multi-species, extending from sub-tropical to sub-Antarctic waters across southern Australia in depths from 20 to 1500m. When the project commenced the primary management tool was individual transferable quotas and a range of input controls. Spatial measures have recently been adopted (e.g. gulper shark closures).

The project was initiated because of concerns regarding declining economic performance in most sectors and an increasing number of overfished species. The aim was to rethink the entire management arrangements for the fishery and identify management options that would deliver better economic and ecological outcomes. A key project component was to bring stakeholders along in the process.

The project was undertaken in two stages: a qualitative (Smith *et al.* 2004) and quantitative (Fulton *et al.* 2007) stage both using MSE. Scenarios were evaluated from 20-year projections of 38 performance measures. For the qualitative stage, projections were expert-based. Importantly, the project team had over 150 years collective experience of the SESSF, which allowed a well-informed qualitative approach to be undertaken.

The performance measures included 13 fishery (e.g. catch, catch composition CPUE, fleet size, discards); 15 economic (e.g. GVP, return on investment, profit quota trading); 8 ecological (e.g diversity, habitat cover, biomass ratios); 6 management (e.g management and research costs, access and stability and TEP interactions) and 2 social (e.g. community perception).

The quantitative analysis was undertaken using the Atlantis model framework (Fulton *et al.* 2005) (Figure 5). The framework simulates the adaptive fisheries management cycle. Underpinning the framework is a biophysical model that represents the ecosystems contained within the area of the SESSF. This includes bathymetry, currents, upwellings and habitats. Biological dynamics cover the main processes (feeding, reproduction, movement, mortality, waste, age). Functional groups are represented by size and diet and age and size structure included for selected species, including the major target species. Anthropogenic drivers other than fishing include changing nutrient loads, and temperature profiles. An example of the complex food web and interactions between key species is shown in Figure 6.

The Fleet Dynamics sub-model allows for multiple fleets, gear, ports, and targeting, impacts (including discarding, habitat modification, etc), and compliance. The monitoring and assessment sub-model provides data from surveys, observers and fisheries records (with error). It includes common assessment models, from simple (e.g. catch curves) to complex (e.g. stock synthesis), as well as index estimation. It also includes ecological indicators as well as traditional fisheries indices.

The Management Sub-model represents the major levers (closures, effort control, quotas, mitigation and gear) and the rules to apply them. Finally, the Socio-economics sub model includes fleet dynamics, spatial allocation of effort, quota trading, markets and public perception.

The modelled projections are intended to provide strategic insights into the consequences and trade-offs associated with each scenario and should not be considered explicitly predictive.

Here we report on four scenarios:

- **Status Quo** – as at 2005, primarily quotas, existing input controls but with 2005 zones in place.
- **Quota on Everything** – an extended quota system, existing input controls, with 2005 zones + some gear specific closures.
- **Integrated Management** – quota system and input controls retained but with structured zoning in all depths (for fisheries management & conservation). This scenario also frees-up gear controls such that vessels may use any gear.
- **'Conservation' Driven** – quota system and most input controls maintained but with very extensive closures - paddocks (closed = 70% <150m; 20+% outer shelf; 80+% slope; 100% > 800m).

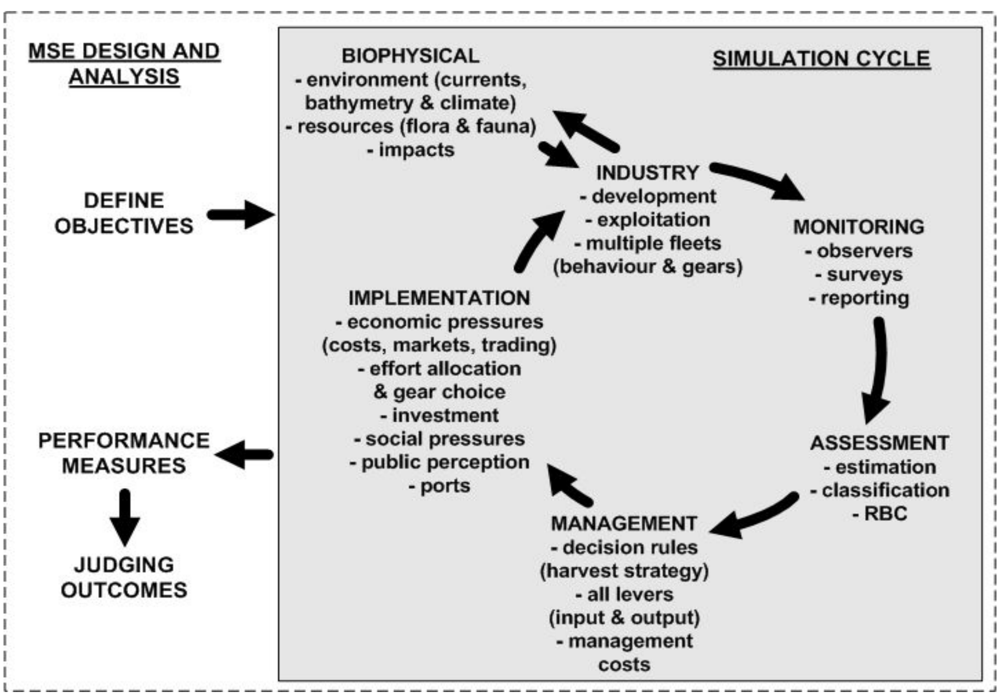

Figure 5: The Atlantis management strategy evaluation modelling framework

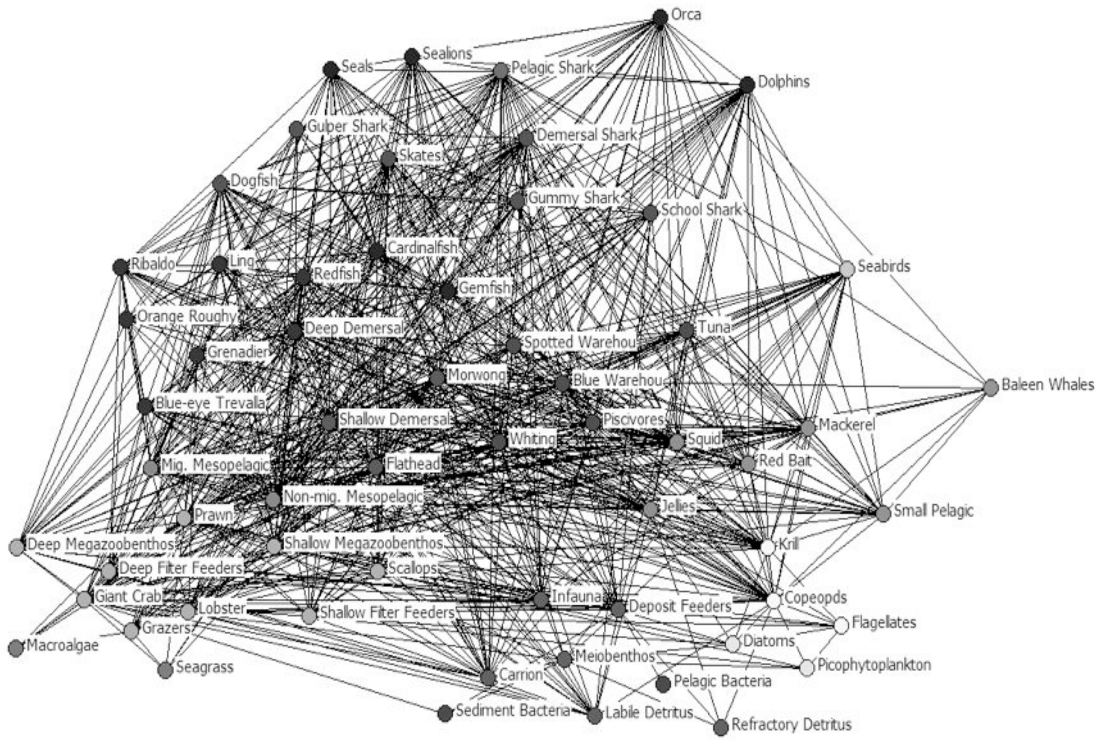

Figure 6: Representation of Atlantis food web and interactions between key species.

The results for these scenarios can be briefly summarised as follows:

- **Status Quo** – effort remains high; there is a push into marginal areas until economic collapse; shift in targeting to extreme trophic levels (both up and down the trophic web); system and public opinion collapses
- **Quota on Everything** – effort remains high until the fleet adjusts (economically driven); the deepwater fishery becomes unprofitable so there is a shift to shelf depths; overcatch becomes an issue; the trawl sectors benefit most
- **Integrated Management** – the fleet readjusts quickly; the footprint is concentrated on biological 'hot-spots'; byproduct quota becomes critical; discarding issues; gear switching not common; good all-round performance
- **'Conservation' Driven** – closures are very restrictive; there is a strong recovery in some species; significant industry and human cost.

These results were broadly similar for both the qualitative and quantitative analyses with over 60% of the indicators showing similar trends in the 20 year projections. However, there was greater variability between sectors and species in quantitative results than the qualitative analysis suggested.

None of the scenarios performed better than all others across all indicators but the integrated management scenario was consistently 'pretty good'. Several key trade-offs were evident:

- conservation versus economics
- short term costs versus longer term pay-off
- as the fisheries declined fleets moved shallower again

Fisheries closures were able to meet some management objectives, as indicated by some performance measures, but not all. They did provide, however, cost effective solutions to some objectives. The results showed there was no perfect strategy, but mixed strategies performed best. Importantly, the scenario that relied most on closures, performed very poorly from a fisheries social and economic perspective. We argue, however, that there are clear benefits in a convergence of spatial management that meets fishery and conservation objectives.

Conclusions

Fisheries spatial management has been used for many years and it is used to meet many different objectives. It is also a key component of EBFM.

In this paper we considered the recent fisheries literature and showed the increasingly explicit reference to spatial management in fisheries science. It is clear from this literature, however, that terminology remains a significant issue and objectives were often assumed.

The habitat ERAEF is an effective method that can inform fishery managers about potentially high risk interactions with habitats.

The gulper sharks example demonstrates the important role that fishery spatial management, through closures and zoning, has in mitigating fishery impacts.

Finally, the 'alternative management strategies' project provides insights into how effective the widespread use of MPAs might be in fisheries management. The results of this project indicated that spatial management should be considered as one of an integrated set of management 'levers' It is naïve to think that spatial management alone is a 'panacea' to solve all fishery management issues.

So in response to the title of this paper; Spatial management in fisheries: the answer to our problems? The answer is yes and no!

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Spatial management of freshwater fish: A case study for Murray cod

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Abstract
Native fish, including Murray cod *Maccullochella peelii,* have declined substantially in the Murray-Darling Basin since European settlement. Management is now focused on population rehabilitation and this is largely undertaken by State agencies and regional catchment authorities. While there is some coordination across States and assistance from Commonwealth agencies, management structures are largely determined by State borders and catchment management boundaries. As a consequence, the management of Murray cod currently differs between States and occurs at a range of spatial scales. Murray cod (an iconic angling species now listed as threatened under the national Environment Protection and Biodiversity Act 1999) is subject to a range of threats which operate at a range of spatial scales. This paper examines spatial issues that need to be considered when undertaking management actions for Murray cod, taking into account the mobility and dispersal mechanisms of the different life stages and genetics of different populations. While eggs are adhesive, larvae may potentially drift up to 740 km depending on river flows. Juvenile Murray cod are relatively sedentary, with limited movements < 1 km, however, adult Murray cod can move up to 120 km upstream. Murray cod are widely stocked from hatcheries and this has been identified as a potential threat to the species. Several different genetic units have been identified, covering river basins of up to 85 000 km^2 in area and these need to be considered when stocking is to occur. Ecological processes that may influence Murray cod populations operate at larger (including whole-of-river) scales which together with temporal scale issues (eg. seasonality), also need to be taken into account. This paper provides an initial approach that allows management decisions to be based on an understanding of the use of spatial scales relevant to the fish rather than scales arbitrarily determined by managers.

Introduction
Freshwater fish live in largely linear river ecosystems that are subject to many land-based threats. These river systems rely on their catchments and are managed by a range of agencies at a range of scales. The range and abundance of most of its native freshwater fish species have suffered major declines (Cadwallader 1977, Cadwallader and Lawrence 1990, Murray Darling Basin Commission 2004) and the rehabilitation of native fish populations is now recognized as a priority, facilitated by the *Native Fish Strategy for the Murray-Darling Basin* (Murray Darling Basin Commission 2004). Management of native fish in the MDB is now undertaken for population rehabilitation, conservation and recreational fishing.

Murray cod *Maccullochella peelii* is Australia's largest freshwater fish, growing to 113 kg (Rowland 1989). It is a highly prized angling species and considered to be iconic. As an important angling species Murray cod, have been widely stocked for recreational purposes (Lintermans 2005). Recent research on this species has provided new knowledge on spawning and larval ecology

(Humphries 2005, Koehn and Harrington, 2005, 2006), habitat selection (Koehn 2006, 2009a, 2009b) and movements (Koehn 2006, Saddlier *et al.* 2008; Koehn *et al.* 2009). Murray cod were traditionally a major part of the diet of aboriginal tribes living adjacent to inland waters, and were an important cultural icon for these tribes (Ramsay Smith 1930, Lawrence 1971). These qualities elevate the importance of Murray cod from being merely fish species to being a significant component of Australian folklore and cultural heritage.

Murray cod have undergone only a marginal reduction from their natural geographic range which covers almost the entire MDB (Lintermans 2007) (Figure 1). Murray cod have, however, declined markedly in abundance (Cadwallader and Gooley 1984, Rowland 1989, Farragher and Harris 1994) throughout this range. All commercial fisheries have now been closed and Murray cod is now listed as a vulnerable species under the Environment Protection and Biodiversity (EPBC) Act 1999 (Environment and Heritage 2003a, 2003b). Fishing for Murray cod is controlled by a range of regulations including a closed season, bag and size limits. Murray cod are subject to a range of threats including: habitat removal; changes to flows; restrictions to movement; interactions with alien species; sedimentation; excessive recreational and illegal fishing; changes to water quality (temperature, salinity, suspended sediment, dissolved oxygen); stocking and genetics (Koehn 2005a). A National Recovery Plan for Murray cod has been prepared following the EPBC Act listing (National Murray Cod Recovery Team 2007) to address these issues and one of the high priority actions is to define management units that may be appropriate for Murray cod.

This paper examines the spatial scales of existing management arrangements, threats that affect the species and the spatial needs of the various components of the Murray cod lifecycle.

Management structures

The MDB comprises four States as well as the Australian Capital Territory (ACT) (Figure 1). Within this geographic range a variety of river systems and corresponding management agencies, catchment management organizations and local government authorities occur. Management of Murray cod within the basin is also subject to Federal government agencies and legislation. The Murray-Darling Basin is one of Australia's largest river basins covering an area of over one million km^2, with the total river distance from the Condamine River source to the Murray mouth being 3,750 km. The spatial scales of each state within the MDB vary considerably, as do river lengths and catchment sizes (Table 1). Consequently, management can occur at a range of scales depending on the jurisdiction, agency, program or management action undertaken. Examples of different management spatial scales include:

- Whole of Basin (eg. Native Fish Strategy; Murray-Darling Basin Commission 2004)
- Species distribution (eg. Recovery plans: Murray cod; National Murray cod Recovery team 2007)
- River reaches (eg. Rehabilitation sites or Demonstration reaches; Barrett 2004)
- Particular areas (eg. Icon sites; Murray-Darling Basin Commission 2003, or River Parks; Phillips and Butcher 2005).

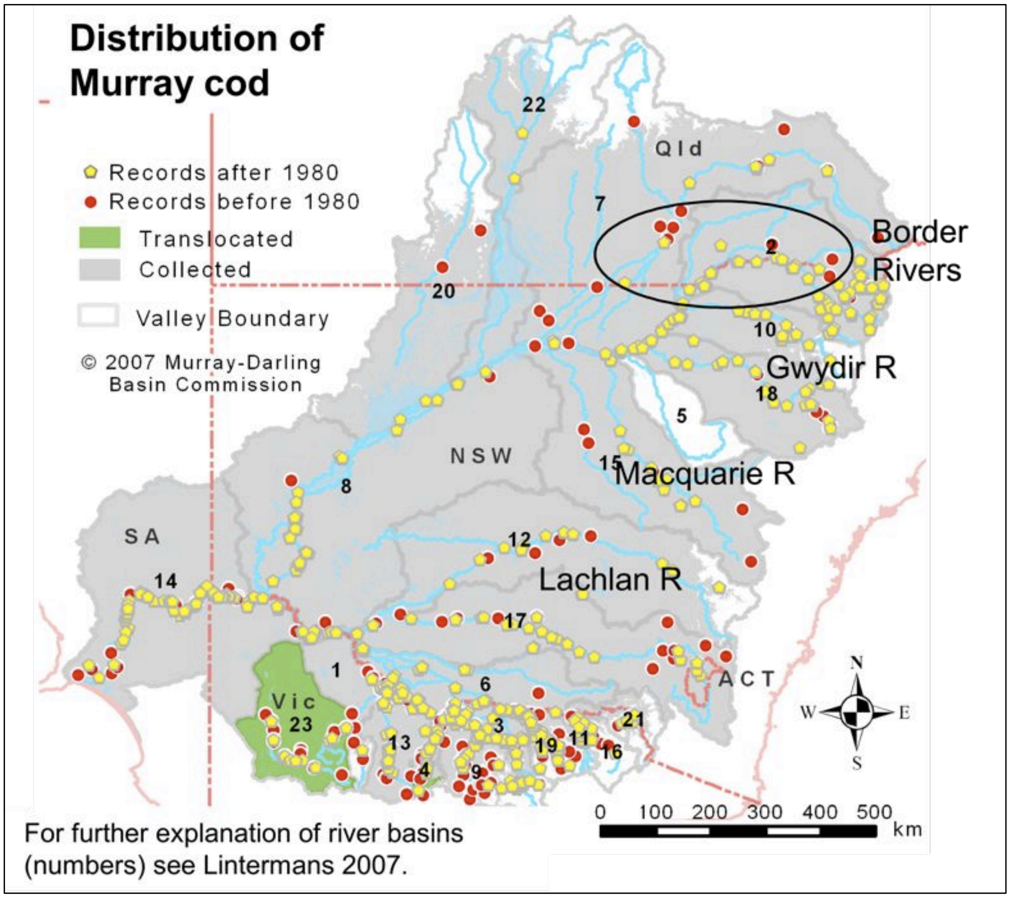

Figure1: The distribution of Murray cod (from Lintermans 2007).

Table 1: Catchment area within each state as well as example river lengths within the Murray-Darling Basin.

Management/river unit	Length (km)	Area (km^2)
Basin/States		
Murray-Darling Basin		106 1469
South Australia		68 744
Victoria		130 474
New South Wales		599 873
Australian Capital Territory		2 367
Queensland		260 011
Rivers		
Border	557	49 500
Moonie	390	15 800
Condamine - Culgoa	690	15 000
Warrego	800	72 800
Paroo	530	76 200
Lachlan	1 484	84 700
Macquarie	960	73 700
Castlereagh	549	17 700
Namoi	858	43 100
Gwydir	668	25 900
Macintyre	321	22 550
Murrumbidgee	1 575	84 000
Darling	2,740	174 800
Murray	2 530	
Mitta Mitta	219	4 720
Kiewa	184	2 050
Ovens	227	7 850
Broken	192	7 330
Goulburn	563	16 800
Campaspe	245	4 ,020
Loddon	392	15 400
Avoca	269	12 000

Threats to Murray cod

The objectives of the *Native Fish Strategy* identify the need to address various threats to native fish across the MDB (Murray-Darling Basin Commission 2004). Similarly, the National Recovery Plan for Murray cod (National Murray cod Recovery team 2010) identifies threats to the species and the recovery actions that may be needed to address their impacts. These threats can operate or be managed at a range of spatial scales.

Fish passage:
Barriers to fish movements posed by dams and weirs are widely recognized as a key threat to fish species on a world wide basis (Cowx and Welcomme 1998) as well as in Australia (Cadwallader 1978, Harris 1984). There is a need to maintain connectivity between habitat patches and fragmented fish populations and providing fish passage past such barriers is seen as an essential step for the rehabilitation of native fish populations (Murray-Darling Basin Commission 2004, Barrett and Mallen-Cooper 2006). Movements of Murray cod occur both in upstream and downstream directions over considerable distances (Koehn 2006; Saddlier *et al.* 2008; Koehn *et al.* 2009) and the passage of such large-bodied fish poses some difficulties for fishway design (Mallen-Cooper pers. comm.). Fish passage can be addressed at a variety of scales, including at specific sites, as part of a larger program which prioritizes barriers for remediation on a State-wide basis (T. O'Brien, pers. comm.), at the Basin level (Murray-Darling Basin Commission 2004) or for a particular river such as the Murray River (Barrett and Mallen-Cooper 2006).

Habitat loss:
Murray cod are a main channel specialist that has high fidelity to home sites with the habitat preferences of both adults and juveniles largely determined by structural woody habitat (Koehn 2009a). The removal of these habitats has been widespread in Murray-Darling Basin rivers, particularly in lowland reaches over a large number of years (Treadwell *et al.* 1999) and its reinstatement is now recommended as a priority action for river restoration (Murray-Darling Basin Commission 2004). Such reinstatement is occurring on a site by site and river reach basis, and our understanding of its effects and fish-habitat relationships is increasing (Nicol *et al.* 2002, 2004; Jarod Lyon pers. comm).

Invasive species:
There are a range of approaches for managing invasive species (see Koehn and Mackenzie 2004), that include national, state and basin-wide approaches depending on the species. For example, there is a national plan for carp control (Carp Control Coordinating Group 2000) and moves toward basin-wide approaches for other species such as weather loach (*Misgurnus anguillicaudatus*) and Tilapia (*Oreochromis mossambicus*) should it enter the Murray-Darling Basin (see Ansell and Jackson 2007). The overall impacts of carp on Murray cod have not been determined (Koehn *et al.* 2000).

Changes to flows
While there is debate regarding the importance of floods and a natural flow regime for native fish recruitment (Humphries *et al.* 1999), it has been suggested that stronger Murray cod recruitment follows years with high flow levels (Ye *et al.* 2000, Rowland 1998, King *et al.* 2009). Murray cod utilize floodplain channels, but generally avoid the floodplain itself, when flows are sufficient (Koehn 2009a). Hence, reduced flows may reduce habitat availability and recruitment levels. Changes to flows can alter downstream larval travel times and hence drift distances (see below). Variations in flow can stimulate fish movements (Mallen-Cooper *et al.* 1995) although this has not been determined for Murray cod. Most flow management occurs on a river reach scale (Close 1990).

Water quality:
Cold water pollution has been identified as an issue within the Murray-Darling Basin and amelioration of its impacts are likely to occur on a site-by-site basis and effect individual river reaches (see Phillips 2001). The impact of cold water release on Murray cod populations has been explored for two river reaches within the Murray-Darling Basin (Todd *et al.* 2005,

Sherman *et al.* 2007). Other sites prone to poor water quality and fish kills could be managed on a more site-specific basis (eg. Broken Creek; see Koehn 2005b).

Angling pressure:
Murray cod are widely sought by anglers with take varying considerably across the species' range (Henry and Lyle 2003). Angling pressure can be greatest close to key population centers and in popular locations although there is little quantification of take on a spatial basis. Angling occurs both in wild fisheries and also in put-and-take fisheries that are managed with stocking from hatcheries. Whilst remaining a politically sensitive issue, angling can have an impact on the population structures of Murray cod and this needs to be considered in management options (Nicol *et al.* 2005). Although management of Murray cod is now coordinated through a National Recovery Plan (National Murray Cod Recovery Team 2010), management is largely undertaken by State agencies and while attempts are made to maintain uniformity, current fisheries management and angling regulations vary between jurisdictions (Table 2).

Table 2: Current angling regulations for Murray cod for each State and Territory across the species' range. (Information from PIRSA 2011, Fisheries Victoria 2011, NSW DPI 2011, DPI&F Qld 2011, Lintermans 2005, pers. comm.).

			State		
	SA	Vic	NSW	ACT	Qld
Regulation					
Closed season	1Aug-31 Dec	1Sept-30Nov	1Sept-30Nov	1Sept-30 Nov	1Sept-30Nov
Bag/possession limit	NA	2	2 (4 possession)	2	2
Minimum size limit	NA	60 cm	60 cm	60 cm	60 cm
Maximum size limit	NA	100 cm			110 cm
Other conditions	Catch and release only fisher		Only 1 > 100 cm		

In some cases there could be valid reasons for differences to exist (e.g breeding may occur later in the southern part of the range due to cooler temperatures, requiring the closed season to end later), however many of these differences are a result of historical factors or differences in timing or regulatory processes.

Important populations of Murray cod have been identified throughout the MDB on the basis that they are either of high conservation value or as high volume angling stocks. The high conservation value populations are often represented by populations that are significant in terms of their superior population size or structure (particularly when this structure suggests strong natural recruitment). Such populations may be isolated from other populations of high value by physical barriers or by habitat fragmentation. Conversely, high value angling stocks focus on populations that satisfy angler (and regulatory) requirements, providing suitably large individuals for angler opportunity. Many of these populations are represented by 'put and take' fisheries often within accessible impoundments that could be managed on a more individual site basis (National Murray Cod Recovery Team 2010). While at first glance some lake fisheries may be able to be managed in isolation, there may be significant connectivity with river populations that need to be considered (Koehn 1996; Koehn *et al.* 2009).

Spatial requirements for Murray cod life stages

As Murray cod lay adhesive eggs that remain attached to hard substrates until they hatch, the protection of spawning habitats (Structural Woody Habitats) is considered vital to their continued survival and can occur at a site scale. Larval Murray cod occur widely throughout the river system (Koehn and Harrington 2005), drifting with the river flow (Humphries 2005, Koehn and Harrington 2006), which provides a dispersal mechanism for this life stage. The period that the larvae spend in the water column as drifting particles is yet to be determined, although suggested to be 5-7 days (Humphries and King 2004) or 4 days for the majority of the population (Gilligan and Schiller 2004). It has also been suggested that there may be diurnal patterns of movement, so not all of this time may be spent drifting (Humphries and King 2004, Gilligan and Schiller 2004). Drift distances will depend on river flows which are highly variable in Australian rivers, including those across the range of Murray cod. Flows in Australian rivers are highly variable by world standards (Crabb 1997) and vary considerably across the species' range, and hence greatly influence drift distances. The Darling River has low relief, especially in the downstream reaches where the river slopes decrease dramatically (Thoms *et al.* 2004). While the Murray and Murrumbidgee Rivers have more reliable precipitation rates, they are now subject to considerable regulation (Crabb 1997, Close 1990), whereas the Darling River experiences large floods and periods when flows can cease for extended periods (Crabb 1997). As a result, flow rates are generally slower in the Darling River and lower reaches of the Murray River where flows are affected by a series of weir pools (Table 3).

Humphries and King (2004) suggested a drift distance for Murray cod larvae of 48 km in the Broken River. This, however, is relevant to that river under those flow conditions. Using the fastest flow rates in the Murray River (Table 3), maximum larval travel distances could be in the approximate ranges of 424 km (4 days drift) to 742 (7 days drift). Inter-annual, seasonal and even daily changes in flows would mean considerable variability in these estimates and under regulated flows the flow variability may be reduced and these distances will be altered depending on the flow regime. Additional research is required to further quantify the spatial scales used by larvae.

Table 3: Travel distances, times and approximate rates for a 'flow wave' in the Murray and Darling Rivers. Data derived from Crabb (1997).

River section	Distance	Approximate travel rate (km/day)
Murray River		
Hume -Yarrawonga	237	59
Yarrawonga - Tocumwal	101	51
Tocumwal - Torrumbarry	257	64
Torrumbarry – Swan Hill	220	55
Swan Hill - Euston	294	74
Euston - Wentworth	289	58
Wentworth – Lock 9	60	60
Lock 9 – Lock 7	69	69
Lock 7 – Lock 1	422	106
Lock 1 – Wellington	203	41
Darling River		
Menindee - Wentworth	507	39

Little is known of the movements or habitat use of juvenile Murray cod, although post-larval young-of-the-year fish have been found in the main river channel rather than in billabongs (Koehn and Harrington 2005). In that study, no Murray cod were caught in downstream drift nets (so it is assumed that no mass downstream movement occurs at this life stage). Any upstream movement by this age class is unknown. In a radio-tagging study conducted over 3 months, juvenile (suggested to be 3 year old) Murray cod were found to have limited movements with a mean range of 318 ± 345 m and maximum total linear range of 864 m (Jones and Stuart 2007). As recolonisation occurs for many other native fish species at early life stages (Mallen-Cooper *et al.* 1995), study over a longer period may discover greater movements. Movements of fish < 650 mm TL (presumed 4-5 year old Murray cod) have also been shown to be limited (Koehn 2006). Adults (> 650 mm TL), however, do show more extensive movements that occur on a seasonal basis with many undertaking an upstream migration from their home site prior to spawning during late winter and spring. These migrations occur for varying river distances of up to 120 km after which the majority of fish return to a location near their original site (Figure 2) (Koehn 2006, Saddlier *et al.* 2008). These upstream movements also utilise floodplain channels when they contain adequate flows (Koehn 2006; Koehn *et al.* 2009). Such migrations also involved upstream movements of fish out of Lake Mulwala into the inflowing Ovens and Murray Rivers (Koehn 1996, 2006; Koehn *et al.* 2009). An example of such movement is given in Figure 3.

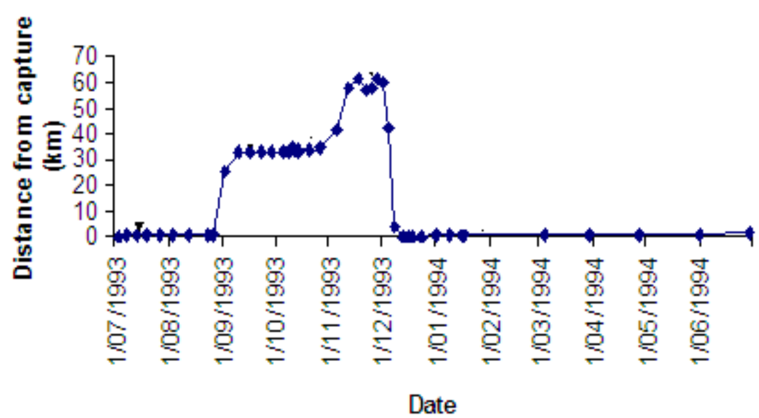

Figure 2: Movement locations obtained over a 12 month period by radio-tracking for a Murray cod from the Ovens River (modified from Koehn and Stuart 2007).

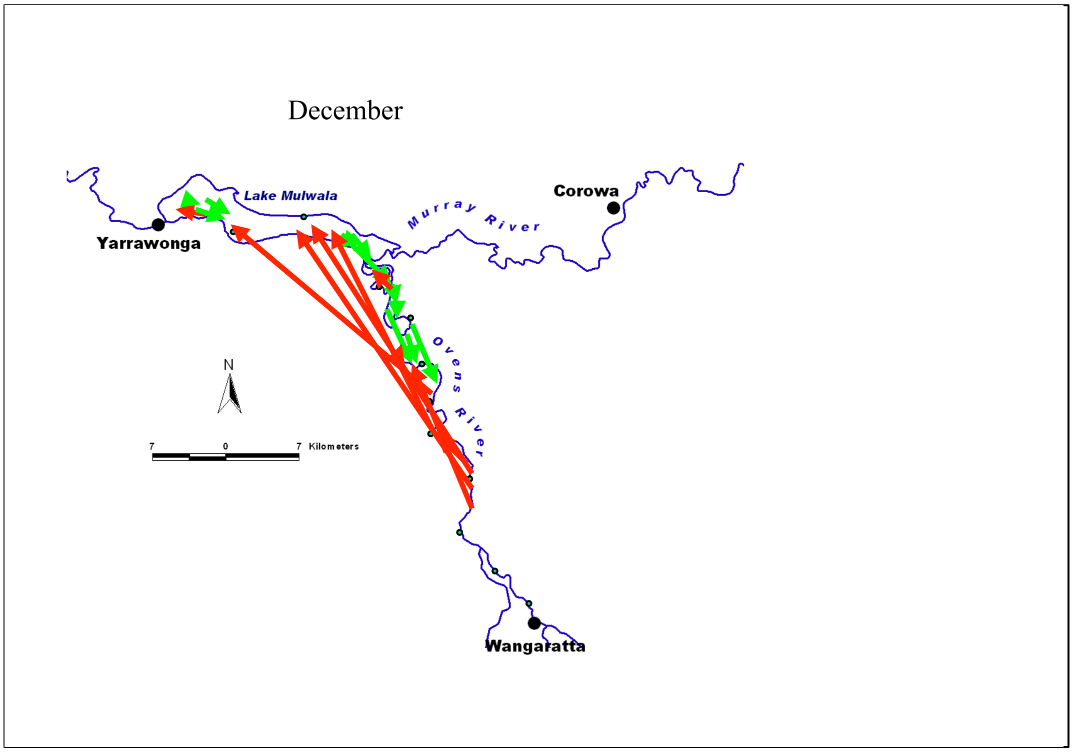

Figure 3: Upstream (green) and downstream (red) movement vectors for Murray cod > 650 mm TL in the Ovens River for December 1993.

An overall model for upstream and downstream movements of larval and adult Murray cod can be summarized in Figure 4. These indicate that movements are not restricted to within the Lake Hume to Lake Mulwala reach of the Murray River and also that opportunities for recolonisation are likely to be affected by the barrier to fish passage that Lake Mulwala could pose.

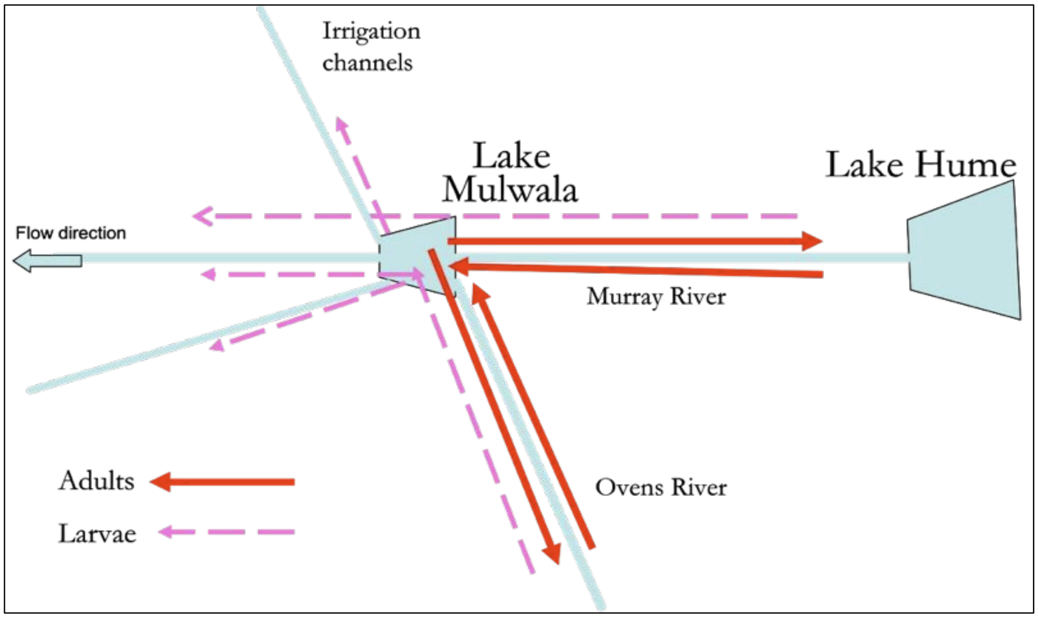

Figure 4: Overall movement model for larval and adult Murray cod from Lake Mulwala and the Murray and Ovens Rivers.

Genetics

As Murray cod are widely produced in hatcheries and stocked for recreational angling, the genetic influence of these hatchery stocked fish has been considered a potential threat to the species (Phillips 2003, National Murray cod Recovery Team 2010). Murray cod populations in the MDB are largely panmictic (one large population experiencing extensive gene flow) with most catchments being genetically similar (Rourke 2007). There are three exceptions to this, in that the Lachlan, Macquarie and Gwydir Rivers contain genetically distinct populations. These catchments all have large wetlands at their downstream reaches that may have caused disruption to movement and therefore gene flow and hence may be responsible for this genetic differentiation. The Border Rivers (Beardy, Dumaresq, Namoi and Macintyre Rivers) also present a distinct cluster which genetically may need to be considered separately (Rourke 2007). Management of genetic stocks could be undertaken on an individual basis for each of these catchments as they are well defined. This would involve spatial scales of up to 84 700 km^2 catchment size and 1,484 km of river length (512 km direct distance) for the Lachlan (the largest) River. Movement of fish stocked outside these catchments may still be able to occur.

Discussion

The mobility of fishes has profound consequences for their management (Smithson and Johnston 1999) with dispersal and connectivity between habitats being critical for the long-term survival of populations (Jungwirth *et al.* 2000). Effective decisions in species management should be based on knowledge of fish movement requirements and made at the appropriate 'riverscape' scale (Wiens 2002, Crook *et al.* 2001). Such management needs to allow for the spatial scales occupied by the species' different life stages and this has been recognized for the management of Murray cod (National Murray Cod Recovery Team 2007). Some of the spatial scale requirements considered for Murray cod are summarized in Table 4. The greatest spatial movements appear to occur within the drifting larval stages. This is similar to the spatial characteristics of the early life stages (larval and juvenile fish) of trout cod (*Maccullochella macquariensis*) which have also been suggested to be the most dispersive stages for that species (Koehn *et al.* 2008). Genetic differences between catchments mean that some populations need to be managed on a catchment basis when fish stocking is undertaken. As the movements of Murray cod can occur over relatively large distances, often in and out of tributaries, some populations need to be managed across State borders and management jurisdictions. This requires coordination and a more holistic rather than site-based approach to management.

Table 4: Spatial scale requirements for important biological aspects of Murray cod.

Biological aspect	Maximum distance (km)	Comments
Habitat		Maintain connectivity between habitat patches
Eggs	0	In situ
Larvae	742 river km	Instream barrier impacts
Juveniles	864 m	Longer term studies needed
Adults	120 river km	Instream barrier impacts
Population genetics	512 direct km	Hatchery stocking managed separately at a catchment

The movement patterns and habitat use by Murray cod includes use of floodplain channel habitats (Koehn 2006; 2009a) and this lateral scale movement must be included in management options for this (and probably other) species. Similarly, the use of anabranches and tributaries (Koehn 1996, 2006, Saddlier *et al.* 2008) means that these connections need to be managed and maintained. The large numbers of barriers that block fish passage in the Murray-Darling Basin have compartmentalized rivers into fragmented units which have disrupted natural connectivity. The rehabilitation of fish passage (eg. Barrett and Mallen-Cooper 2006) will reverse this process and allow fish species to be managed at larger scales. Instream barriers may also impact upon larval drift distances, potentially reducing overall dispersal and subsequent distribution. Movement over (or under) weir gates can result in larval deaths (Baumgartner *et al.* 2006) and loss into irrigation channels has been recognized as a serious threat (Koehn and Harrington 2005).

Connectivity and continuity of habitats is important for Murray cod management and as rehabilitation of woody habitats is undertaken, the distance between habitat patches should be considered. For example, because of the relatively limited movements undertaken by trout cod it has been recommended that the rehabilitation of structural woody habitat patches should occur less than 1 km apart to allow for rapid recolonisation by adult fish (Koehn *et al.* 2008).

The restricted movement paradigm (Gowan *et al.* 1994, Rodriguez 2002) suggests limited movements by fish and this has often led to management only being considered at local scales. This paradigm has been questioned in big rivers (Crook 2004) and appears not to apply to Murray cod (Koehn 2006; Koehn *et al.* 2009). This paper illustrates that this 'small-scale' view for management must be transformed into a more holistic approach that encompasses larger scales for Murray cod. Important ecological processes, which can influence many important aspects of fish populations (eg. flooding and recruitment) may operate at larger (eg. whole of river) scales and hence they cannot be managed at smaller scales.

While discussions in this paper concern spatial scales, a temporal scale also needs to be considered for many aspects of management. Seasons influence adult movements, spawning and larval drift, all of which are aspects that have been considered when instigating management actions such as closed seasons. Such considerations may provide good reasons for variations in management such as the timing of fishery closures within different regions (eg. northern and southern extents of a species' range due to temperature and seasonal differences).

While this paper has concentrated on Murray cod, other species will have different life histories, habits, movement patterns and spatial requirements and hence may need to be managed at different scales (eg. Golden perch; see O'Connor *et al.* 2005). This paper provides an initial approach that can easily be modified and applied to the management of a range of other fish species to allow for management decisions to be based on an understanding of spatial scales relevant to the fish rather than scales arbitrarily determined by managers. As the movements of Murray cod can occur over relatively large distances, often in and out of tributaries, some populations need to be managed across State borders and management jurisdictions. This requires coordination and a more holistic rather than site-based approach to management.

Spatial scale issues for the management of Murray cod

- One spatial scale doesn't fit all management issues
- Different life stages have different spatial requirements
- Some threats can be managed by site while others need to be managed at a greater scale
- River management must include the floodplain not just the main channel
- Some populations (eg. Lake fisheries) could be managed by site but connections to rivers need to be considered

- Some populations need to be managed across State borders
- Fish passage is needed in both upstream and downstream directions
- Management needs to be considered at larger scales
- Links to tributaries and anabranches need to be ensured
- Genetic units for stocking should be considered at the river basin scale where needed
- Many ecological processes operate and must be maintained at much larger scales

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The value of fishery dependent data for fine scale spatial management: Tasmanian examples

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Abstract
Spatial management has always been needed for patchily distributed species, for example, abalone and scallops. However, successful spatial management requires detailed spatial information. Fishery Independent data for this purpose is expensive to obtain, and especially so for large scale, spatially distributed fisheries.

One solution to the problem is to use the fishing industry to gather information as they go about their business. Modern technology has overcome most of the problems associated with ensuring that such data is credible and in minimising the cost and effort to the fishery.

We use examples from fisheries in Tasmania to illustrate the success and possibilities of this approach. For scallops a combination of industry based survey is used to identify potential scallop beds in a rotational "paddock fishing" harvest strategy. Electronic measuring boards are used to simplify and improve the quality of size distribution data. In the abalone fishery the potential of a combination of GPS and depth data loggers is being used to understand the fine scale spatial distribution of effort. Combining these with detailed habitat mapping we are able to better understand the risk of serial depletion and to characterise productivity around the coast.

Introduction

Management of many fisheries around the world uses a scale that is often unmatched to that of the species being managed. Management is based on data collected at the scale of reporting blocks, which seldom equates to a meaningful description of the patchiness of the distribution of the species or the spatial variation in a range of life history parameters. Fishery Independent data becomes a valuable source of information to explore the relevance of Fishery Dependent data, particularly as it relates to the unfished biomass.

The response to the problem of this mismatch in scales is to attempt to characterise catch and effort at a finer scale, but this usually encounters at least two problems: collecting, managing and interpreting larger amounts of data and the cost of doing Fishery Independent sampling that is capable of validating the Fishery Dependant information.

This presentation examines these problems using two Tasmanian examples: the Scallop Fishery and the Abalone Fishery. It emphasises why finer scale assessment is needed, illustrates how the data problems are being overcome in these fisheries, and shows how technological advancements can overcome problems normally associated with Fishery Dependent data.

A comparison of Fishery Independent and Fishery Dependent data are provided in Table 1.

Fishery Dependent data is biased because it only samples commercial concentrations of a population. The method of collection is in itself often selective and only representative of legal biomass. However, it is cost effective in terms of collection.

On the other hand Fishery Independent data is usually more representative of the population (because different methods can be employed to sample different fractions of the biomass, escape gaps can be closed to sample smaller animals, and by-catch can be kept). It can be randomised and/or stratified to make the sample less biased and more representative. But, it is usually much more expensive to collect and as a result may significantly lack coverage.

Table 1: A comparison of the advantages and disadvantages of Fishery Dependent and Fishery Independent surveys (for explanation see text).

Fishery Dependent	Fishery Independent
– catch estimate	– population estimate
– selective	– size and undersize
– legal size	– random, stratified
– potentially biased	– expensive
– cost effective	– may lack coverage

The Tasmanian Scallop Fishery

A formal survey of the Tasmanian scallop fishing grounds in 2000 only found one small bed of scallops which lay across the boundary between Commonwealth and Tasmanian waters.

The Commonwealth fishery had been shut in 1999 and stayed shut, and the Tasmanian fishery closed in 2000 mainly as a result of a Fishery Independent survey conducted by the Tasmanian Aquaculture and Fisheries Institute (Semmens *et al.*, 2000). At that time only a single small bed of commercial scallops was identified. A subsequent Industry survey in October 2001 (Haddon, 2001) found small scallops outside of the known bed but it would take at least three years for them to grow to legal size.

Importantly, there were so many permits in both the Tasmanian and Commonwealth fisheries that the industry had the capacity to fish out any bed of scallops discovered and opened.

Given a fishery opening this over-capacity led to "boom and bust" fishing where a glut was followed by a scarcity of product. The marketing of the product in these circumstances is suboptimal as a consequence of uncertainty of supply.

The Paddock Fishing Strategy

Instead of the "most open, little or none closed strategy" (as used in Commonwealth fishery), an arrangement of "most closed little open strategy" was proposed as the basis of what we term "detailed spatial management". This has been called the *paddock fishing strategy* by Industry.

If the distribution of scallop beds was known, together with the average size and approximate abundance of scallops in each bed, then it was possible to plan the harvest of each bed through time with an objective of ensuring a fishery each year, focussing on the biggest most valuable scallops at any one time, spreading the "boom" years across many more years by limiting the fishery to more sustainable catches. Importantly this required a decrease in effort and a decrease in the average annual catch.

The strategy had many advantages:

- The rotational harvesting within paddocks increased the chance of a fishery every year (maintains markets, infrastructure, and regional labour force).
- The harvest strategy left large amounts of undisturbed scallops which were perceived to increase the chances of further successful spawning and large scale settlement of spat.
- The harvest strategy focused effort on small areas so that any negative effects of dredging were localised and time was available for recovery before further dredging occurred.

The big disadvantage was that the strategy had a large requirement for information – far more than could be obtained, at a reasonable cost, from Fishery Independent sampling. The necessary information included the location and extent of all scallop beds and the size distribution of scallops present.

The solution was to develop a scheme whereby Industry members themselves would conduct surveys searching for and characterising scallop beds. The information had to be credible and obtained with as little supervision as possible.

Figure 1 shows all VMS (vessel monitoring system) data available for 2003, 2004 and 2005, illustrating the patchiness of scallop beds. Note that each was in a different state of condition with different mean scallop sizes. As a result of the patchiness, different beds were fished in different years as a result of their individual biological characteristics (size and condition).

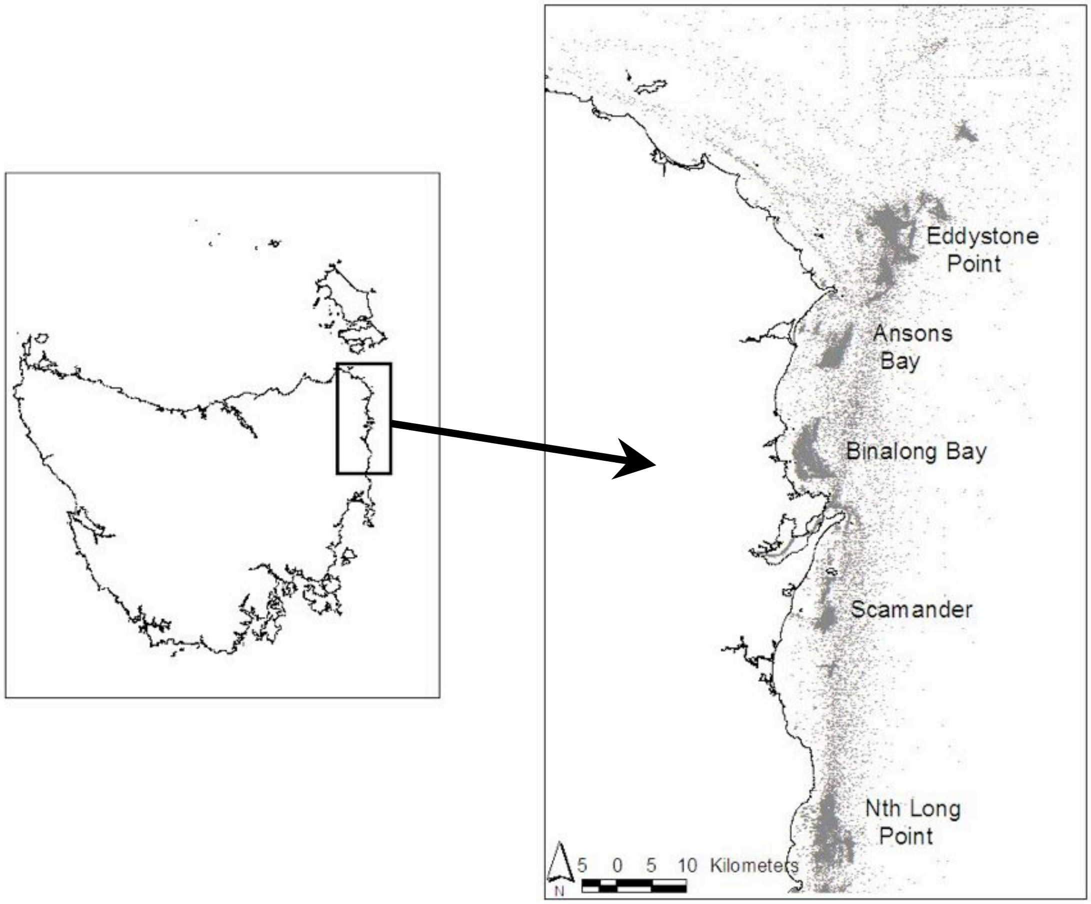

Figure 1: VMS data for the scallop fishery for the period 2003-05 off the east coast of Tasmania (after Haddon *et al.*, 2006) identifying the extent and location of fished scallop beds.

The spatial extent of the fishery and the spatial and temporal heterogeneity characteristic of the beds demonstrated the problem. Management needed a way of getting all this data between seasons to plan for following fishing seasons, but Fishery Independent sampling simply could not achieve this in a cost effective way.

Management needs included:

- Determining the number and spatial distribution of beds.
- Determining the abundance of scallops in each bed - were they big enough to fish and what size were the scallops (note the 90 mm legal size and 20% discard rule which states that fishers may not fish a bed where more than 20% of scallops are undersize).

Industry in turn needed to know the condition of the scallops because this was very important for the market.

The solution to the problem was a Fishery Dependent survey design in which Industry collected the data under the instruction of a research team (Harrington *et al.*, 2007). This included several elements:

1. Liaison with Industry to determine:

  - Where they should look depending on whether we wanted to monitor a known bed(s) or find a new one(s).
  - How many boats were needed to effect the result – for example, when looking for scallops it is often better to use multiple boats in a line.
  - Appropriate levels of training on how to determine the number of scallops caught and how to measure a random sample.
  - Regular data inspection to ensure data integrity.

2. Observers. Generally at least one research observer was provided on each survey or at least was in constant phone contact with fishers

3. Use electronic measuring boards that allow the down-loading of all measurements in a fast and efficient way.

The 2005 Industry survey

The results of this method have been very encouraging. In 2005 a survey was conducted in Banks Strait and east of Flinders Island (Figure 2). The survey was characterised as follows:

- Eleven vessels were positioned in a line (individual tracks shown in Figure 2), with a TAFI observer directing operations on the middle vessel.
- The survey began in the south with a transect up through Banks Strait and then split into two separate transects off Flinders Island.
- Each vessel fished its normal operation from which we were able to collect catch rate data, size distribution of the catch, location of shots, and bed extent.
- Lastly we checked the health of the bed off Babel Island (northern most bed East of Flinders), as this was discovered in 2002 and had not yet been fished.

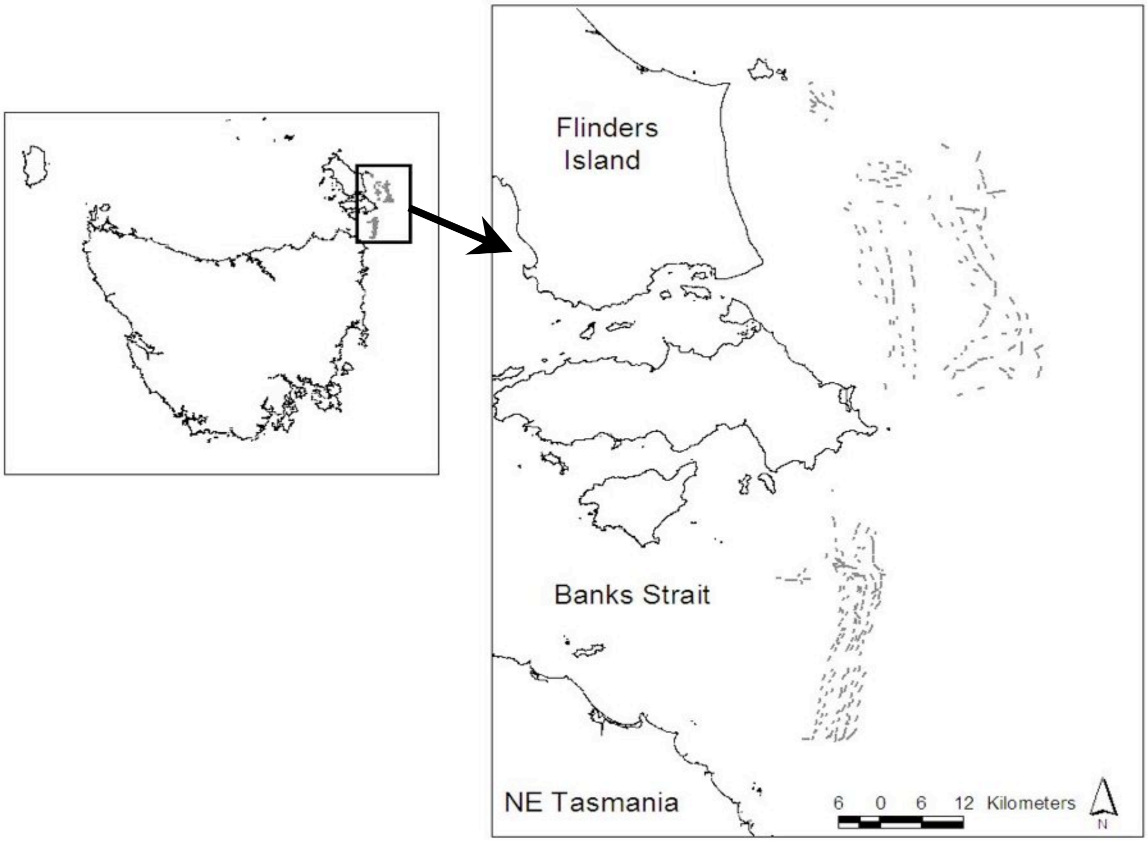

Figure 2: The survey paths of the 2005 Industry based survey of the scallop resource off the east coast of Tasmania (after Harrington *et al.* 2006).

The findings and recommendations from the 2005 industry survey were as follows:

1. Three distinct beds were identified: Banks Strait, east of Flinders Island, and south of Babel Island (Figure 3).
2. The condition (size, density and age of scallops) of the bed off Babel Island revealed that the bed was in decline, scallops were dying off and the bed was unlikely to last until the next season. Therefore the bed was opened in 2005 so as not to waste the resource. This produced the management recommendations as follows:
    - Increase in the 2005 Total Allowable Catch (TAC) so it could be opened
    - Exemption order for legal minimum length from 90 mm to 80 mm
    - Extended fishing season
3. Two of the beds identified were new:
    - The Banks Strait bed which was destined to support the fishery in 2006 and 2007
    - Potential for a bed off Flinders Island (south) for the future.

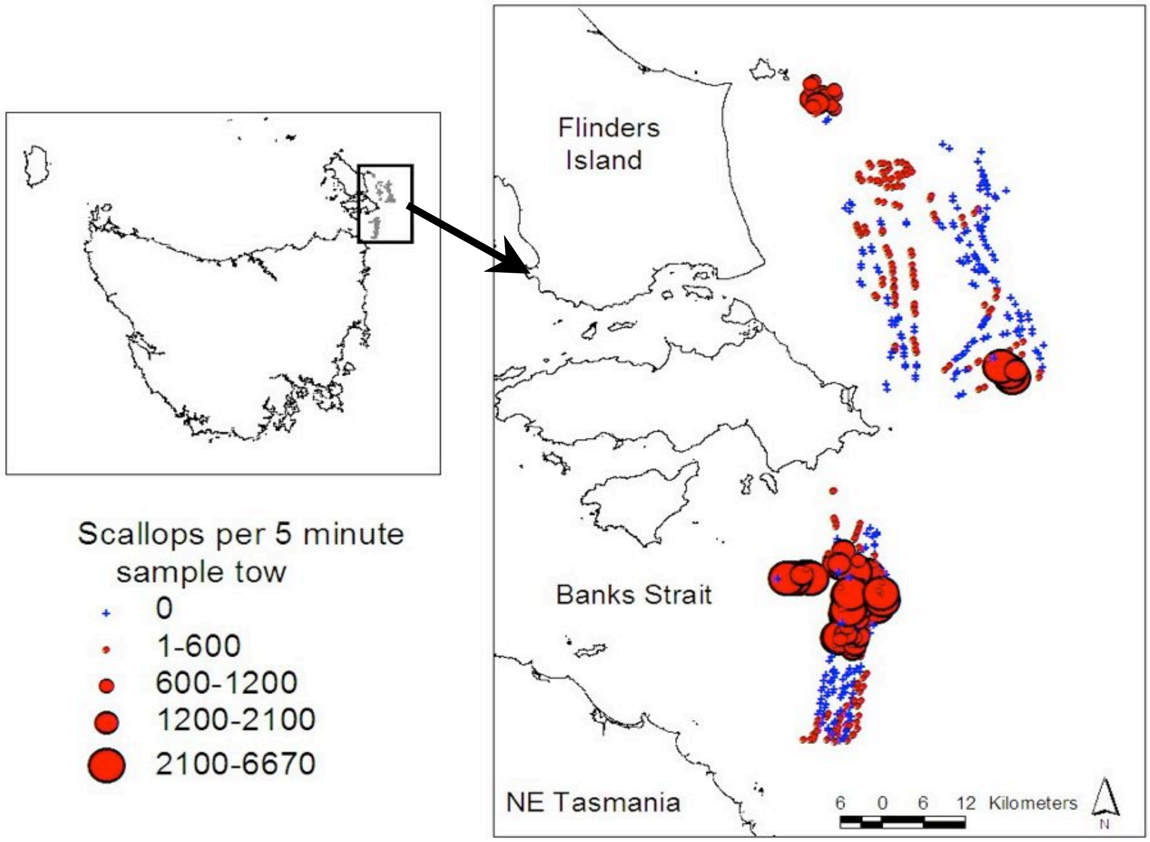

Figure 3: CPUE in the 2005 Industry based survey off the east coast of Tasmania (after Harrington *et al.* 2006).

In addition to the use of Industry surveys to collect data on the status of the stocks, a further innovation was the use of electronic measuring boards to improve the accuracy of the biological data being collected by the fishers. This information was required to evaluate the 20% decision rule and therefore it was very important to have detailed length frequency information.

This was illustrated during the survey where two vessels used newly purchased electronic measuring boards, while a third vessel used the old style manual measuring boards. The results are summarised in Figure 4. The data from the manual measuring board revealed the practise of rounding error, roughly equating to multiples of 5mm. Operators either failed to detect differences at the mm scale despite this being possible, or didn't understand why it was important to get size to the nearest mm, or perhaps they did, so they rounded up to the nearest 5mm!

The data from the electronic boards was a much smoother length frequency histogram. This information was collected more quickly, requiring fewer operators, and was less prone to operator error, especially transfer of data post survey. Measurements were downloaded from the computer and the new model measuring boards had a memory stick that could be sent to IMAS or uploaded on the web.

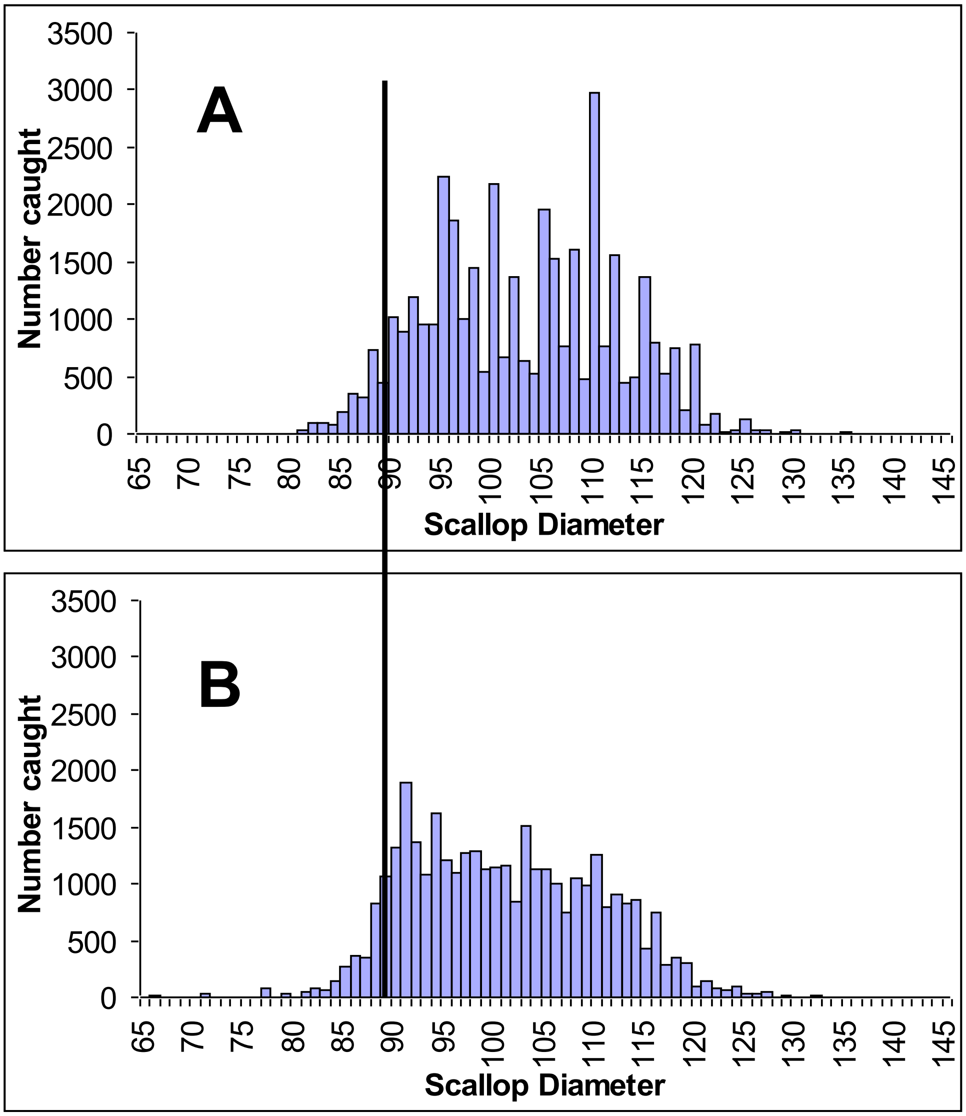

Figure 4: A comparison of length frequency data obtained using manual (A) and electronic (B) measuring boards. The minimum legal size of 90mm is illustrated (Harrington unpublished data).

In summary, we believe that this is an example of ESD Fisheries in action, with triple bottom line (social, economic and ecological) outcomes:

- The data on scallops was only possible because of the strong industry participation in management of the resource (social outcome).
- This has led to a more effective harvest strategy (social and economic outcomes).
- Fine scale spatial management has led to the greater likelihood of sustainable harvest (social, economic and ecological outcomes).
- The paddock fishing strategy has led to a reduction in the effects of fishing, effectively allowing the fallowing of large areas in which the scallop fishery operates (ecological outcomes).

Other benefits of fine scale data

A practical spin-off benefit of collecting fine scale data was illustrated on the announcement of the candidate MPAs in the South-east Marine Region by DEH in December 2006 (Figure 5).

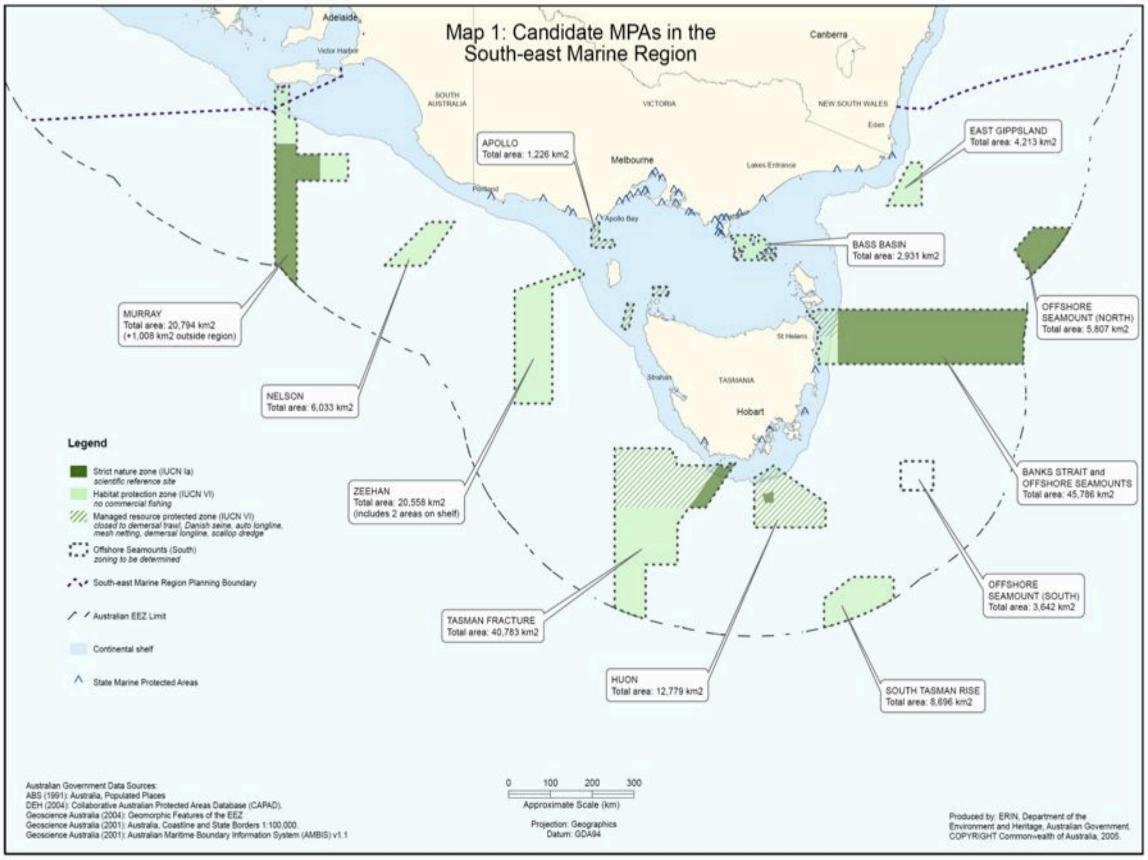

Figure 5: The candidate MPAs proposed by DEH for the SE Region in December 2006 (Buxton *et al.* 2006).

Buxton *et al.* (2007) were able to use fine-scale industry survey data (Figure 6) to illustrate the potentially devastating impact of the proposed Banks Strait Marine Protected Area (MPA) on the scallop fishery. This particularly related to the proposed beds north of Eddystone that were destined to be fished in 2007 (Figure 6b), something that historical Catch-Per-Unit (CPUE) data could not illustrate (Figure 6a).

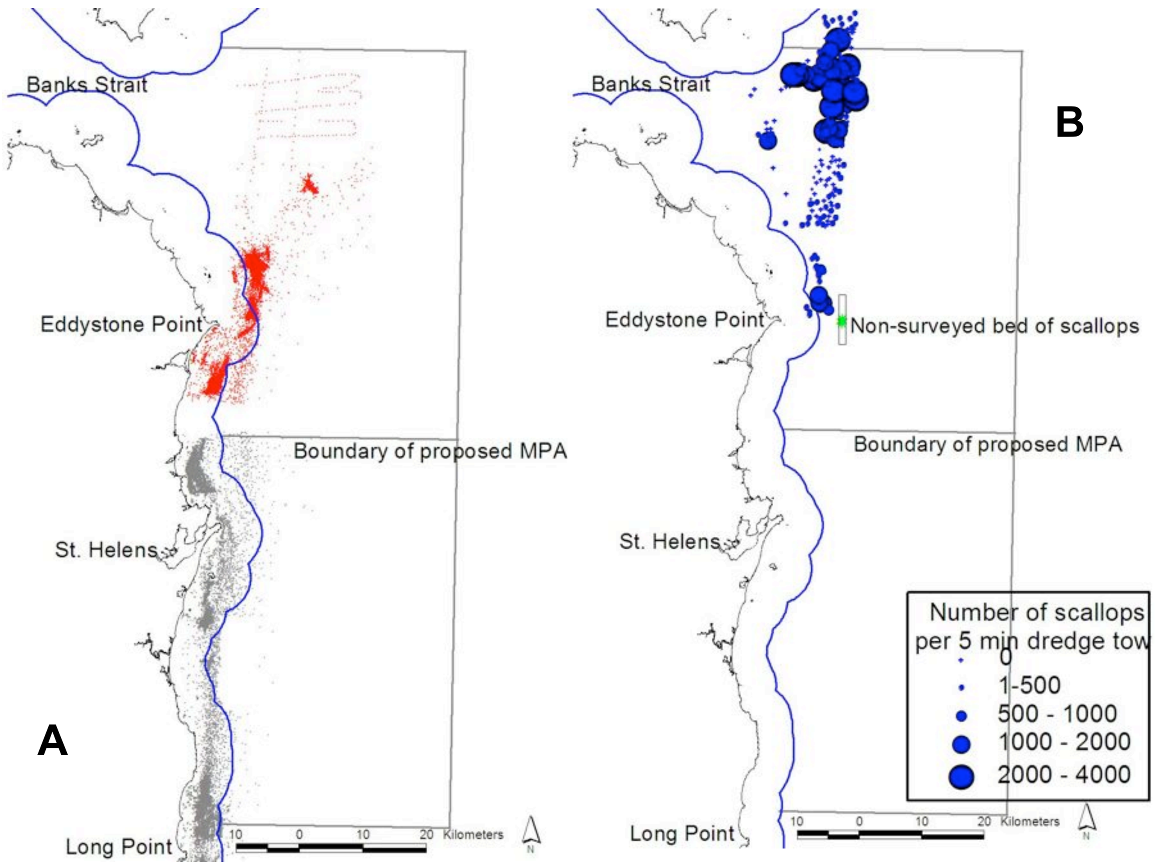

Figure 6: A. Illustration of VMS positions of the scallop fleet during the 1999 (red) and 2003 (grey) fishing seasons. B. The beds proposed in the 2005 season (cf Figure 3) (after Haddon *et al.*, 2006 and Buxton *et al.* 2006).

The fine-scale CPUE data, combined with industry survey data were used to propose an alternative MPA configuration that avoided most of the interaction with the scallop fishery, without compromising the benthic conservation values proposed by the Commonwealth, a win for both sides (Figure 7).

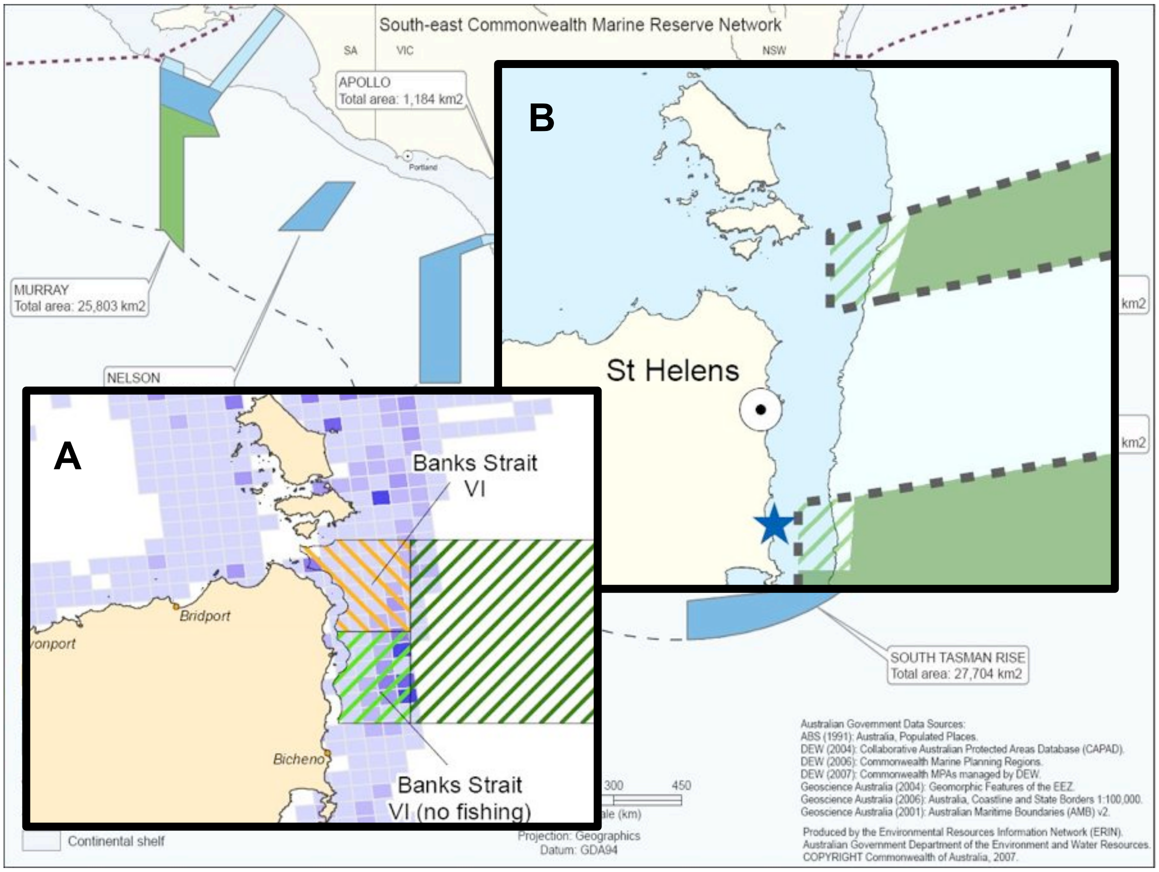

Figure 7: The proposed (A) and alternative (B) MPA configurations for the area off Banks Strait (after Buxton *et al.* 2006).

The Tasmanian Abalone Fishery

Several major abalone fisheries have collapsed to the point of closure (California, British Columbia, South Africa) or have diminished to a fraction of their former productivity (Mexico, Japan, Asia) (Karpov *et al.* 2000). Rapid decline of these fisheries with little apparent warning has been blamed on the failure of Fishery Dependent CPUE data to identify serial depletion (Karpov *et al.* 2000).

Serial depletion effectively being a shift in fishing behaviour by the diver and the fleet in response to declining abundance enabling reasonable catch rates, while masking the actual decline in stock abundance. As a consequence the reliance on fishery dependent data has been widely criticised, and condemned. The core of the problem however, is not the reliance on data provided by fishermen, or the adequacy of CPUE as an index of stock abundance, but the scale and at which the data are reported.

In spatially structured stocks (productivity, biology and marketability), the absence of spatial management (zonal TAC's and size limits) simply compounds the problems of serial depletion, as divers increasingly fish in areas that are convenient, or where market preferences provide an incentive *not* to fish in certain parts of the fishery. This leads to the situation where the divers will increasingly try to take the TAC from a smaller proportion of the fishery (e.g. East/West coast Tasmania 1997–1999).

The failure to capture Fishery Dependent data at an appropriate scale, and to manage a spatially structured stock *places a heavy reliance* on Fishery Independent assessments of the exploitable biomass, which are very rarely available because of the costs and time associated with the collection of data.

The tyranny of scale

Prince (2003) recognised the difficulty of obtaining both Fishery Dependent and Fishery Independent data at an appropriate scale to capture the variable nature of abalone stocks, and the complexity of using that information to manage a spatially structured fishery at an appropriate scale. In the context of highly structured abalone fisheries, he described this as a "*tyranny of scale*", and proposed a solution of co-management or self determination by the fishermen. Jeremy Prince also recognised and respected the knowledge base of the fishermen, and their desire to pursue sustainable fishing practices, and has championed their ability to collect data worthy of use to manage a fishery.

The co-management process involves diver based assessment and management of individual reefs, including setting of size limits and catch targets for individual reefs (effectively distributing the available TAC in an appropriate way across the fishery). The Western and Central Zones of the Victorian abalone fishery have had formal co-management agreements with the Fisheries Victoria for several years, and Rob Day (Univ. Melbourne) and Jeremy Prince have FRDC funding to expand, improve and study industry based fine scale management of abalone stocks.

The approach proposed by Jeremy Prince involves collaboration and agreement by divers about discrete areas of the fishery. This is achievable when the number of divers and the number of discrete components are relatively small, and there is a high degree of cooperation among the catching sector.

In Tasmania, where the fishery is highly spatially structured, number of discrete areas is large (thousands) and the number of divers that must form a consensus is large (> 80), and research funding is scarce, this co-management approach to fine scale management is not considered workable (Figure 8).

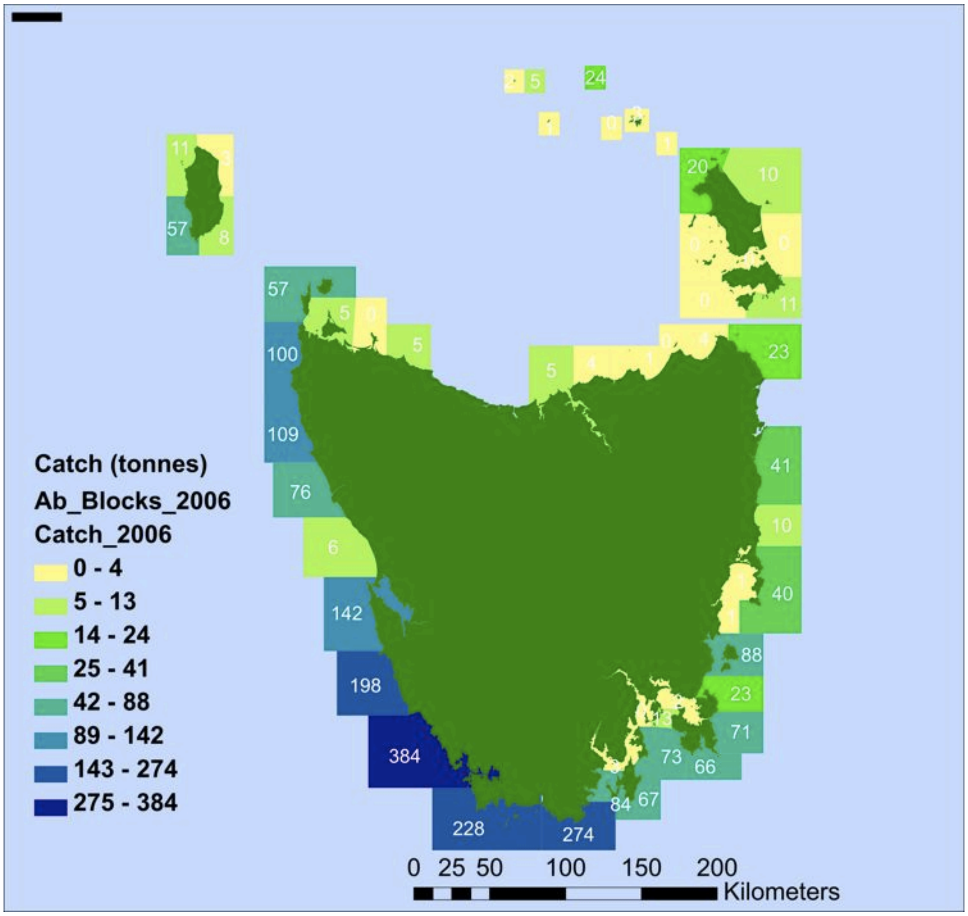

Figure 8: Tasmanian blacklip abalone catch (tonnes) for 2006 by statistical reporting block

The current fishery assessment system is weak and risky, and is unable to identify change in stock abundance at an early stage. The success of the fishery has relied heavily on a largely conservative industry. However, changes in the nature of the fishery and new economic drivers (market preferences, fuel and labour costs, exchange rates) require an assessment system with greater sensitivity, and additional performance measures. Central to this is the ability to detect changes in diver and fleet behaviour at small spatial scales.

The current requirements for reporting of fishing activity are unchanged for more than 30 years. In the case of some early divers, more detailed information was recorded by some abalone fishermen than is required today. While the current system of reporting, pooled catch (kg) and approximate effort (hrs) for each day's fishing within a large geographical area (15km–30km of coast) has remained unchanged since the start of the fishery, the fishery has changed significantly.

In the late 60's and early 70's the fishers were owner-divers working in an immature, or virgin fishery, there was relatively little investment in the fishery, with the catch sold largely in cans or as frozen product. In 2007, the divers were largely contract divers with little personal investment, working in a mature fishery, with total investment > A$2billion, an ITQ system, and the catch sold primarily (> 65%) as a live product. Given that a) the Industry based fine scale management approach is not feasible in Tasmania, and b) that the fishery is spread across a very large coastline, is spatially structured, with 125 divers and over 6000 dive events/year, and limited research resources to collect fishery independent data, at what scale can we effectively assess and manage abalone?

The E-data data alternative

Future sustainability and profitability of the Tasmanian abalone fishery will be dependent on an ability of managers/researchers to identify and react more quickly to change in stocks, and a management framework that controls over-exploitation of sub-stocks because of socio-economic drivers (safety, cost of fishing, market preference). To deliver this, we need to adopt two new approaches:

1) To capture data on fishing activity at a scale appropriate to the management needs, and doing this in a *cost-effective way* across the entire fishery with simple electronic data capture techniques.

2) A spatial management framework that establishes sustainable catch targets for sub-components of the fishery, and performance of the fishery in those areas assessed using indicator variables and performance measures with associated decision rules. Model and expert-based Management Strategy Evaluations will inform managers and industry of the risks of potential management options where trends in indicator variables and/or decision rules identify a change is required.

The first component of this new approach is collection of cost-effective Fishery Dependent data. While there may be issues with the culture of fishermen and reporting of fishing activity, the biggest failure has been that researchers and managers do not appear to have critically reviewed the way Fishery Dependent data has been collected in the past, particularly in relation to resolution of reporting.

If abalone abundance is low, divers spend little time at a site (15–20 minutes), before moving to a new site, or revisiting known productive sites. Reporting at large spatial scales, combined with pooling catch and effort across multiple dive events to give daily totals means this spatial component of diver (or fleet) dynamics is lost. The loss of spatial information is the inherent danger in relying on Fishery Dependent data recorded at relatively large spatial scales, and not the reliance on Fishery Dependent data per se, as often argued. As most fisheries (vertebrate and invertebrate) report at large spatial scales, this loss of information is a common and important issue, and is therefore surprising that so few attempts to redress this issue are evident.

The Electronic-data (E-data) system being developed in Tasmania involves a shift to reporting of catch, effort and location for each dive event, rather than pooling across all dive events per day. This is a simple, but important conceptual change in the way we report fishing activity. Each dive event has a number of unique parameters; diver, location, time, catch, effort, depth profile, habitat and sea state. When data are given as daily totals, only one of these parameters is retained – diver.

The electronic under trial approach involves a GPS logger to provide time & location, and a depth logger to provide effort at depth. Catch for each dive event can be recorded electronically (via GPS logger) or manually.

The technology is illustrated in Figure 9. Note this illustration is over 20 years old but boats and equipment used by divers has improved only marginally since.

A weatherproof GPS receiver is attached to the vessel, developed by local electronics company SciElex to our specifications, and records latitude, longitude, date, time and vessel speed at 10 second intervals.

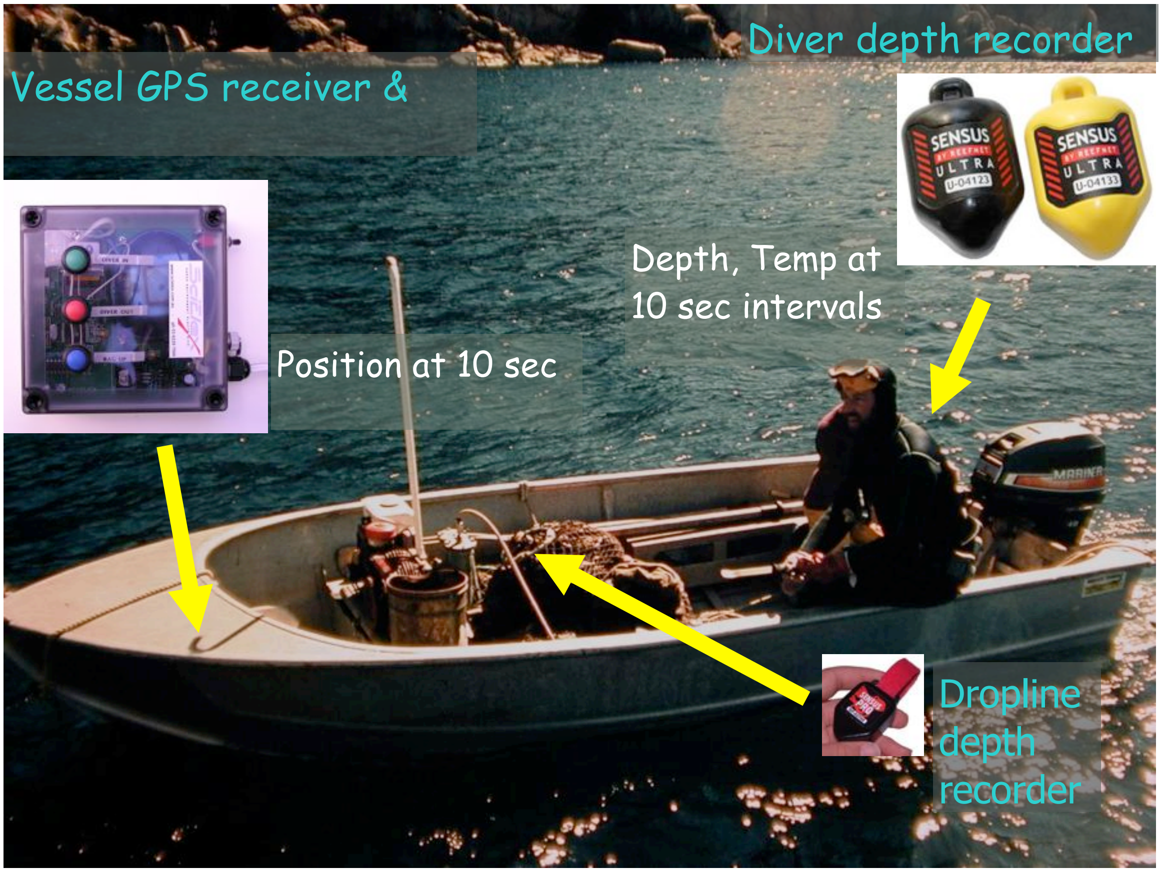

Figure 9: Illustration of the E-data technology being used to collect fine scale fisheries data in the Tasmanian abalone fishery.

Each diver wears an electronic depth logger with solid state memory, and no moveable parts. The logger automatically turns on when a pre-defined pressure (in mbar) is detected indicating the diver has descended below 0.5m. The depth logger records pressure, temperature, date and time also at 10 sec intervals.

An additional component involves a depth logger on the line used to retrieve bags of abalone from the diver. As the vessel is immediately over the diver on retrieval or "net exchange", the exact position of the diver at that point in time is known. This information may be of use in identifying patchiness in abundance by looking at clustering of locations of net exchange points (not illustrated).

Preliminary findings

The ability to obtain precise co-ordinates of each catch event means researchers and managers can be more innovative in our use of Fishery Dependent data. Two examples are given here. The first involves delineation of the area utilised during each dive event, whereas the second uses a more standard approach of quantifying effort or catch within grid cells, but at a much finer scale (100m x 100m cell size).

Potential for analysis of dive location for detection of fleet dynamics

If the location of each dive event is known, then the spatial component of changes in diver behaviour can be identified and quantified. For example, repeat visits to the same dive location, number of dives/day, and shifts to increasing depth at locations where shallow reef areas no longer support good catches.

Kernel Density Estimators (KDE) are used to generate polygons of effort intensity (Figure 11). The outer dark polygon identifies the 95% contour of effort density, effectively identifying 95% of the area traversed by the vessel. The inner light polygon identifies the 50% contour polygon. Essentially the vessel spent 50% of the dive within the area bounded by the light blue polygon. The ratios of the 50% and 95% polygons are being investigated as a potential Indicator variable, long with standard patch analysis metrics such as area-perimeter ratios.

In highly productive areas such as the South-East, the intensity of fishing effort is extreme. Effort maps based on GPS data (Figure 11), show the intensity and distribution of effort at a very fine scale. The level of overlap through time, and with other divers can easily be calculated from maps, and total effort and productivity of the fishery can be monitored. When the fisheries are assessed at typical statistical reporting block or sub-block scale (km's to 10's of km's), this intensity of effort is lost.

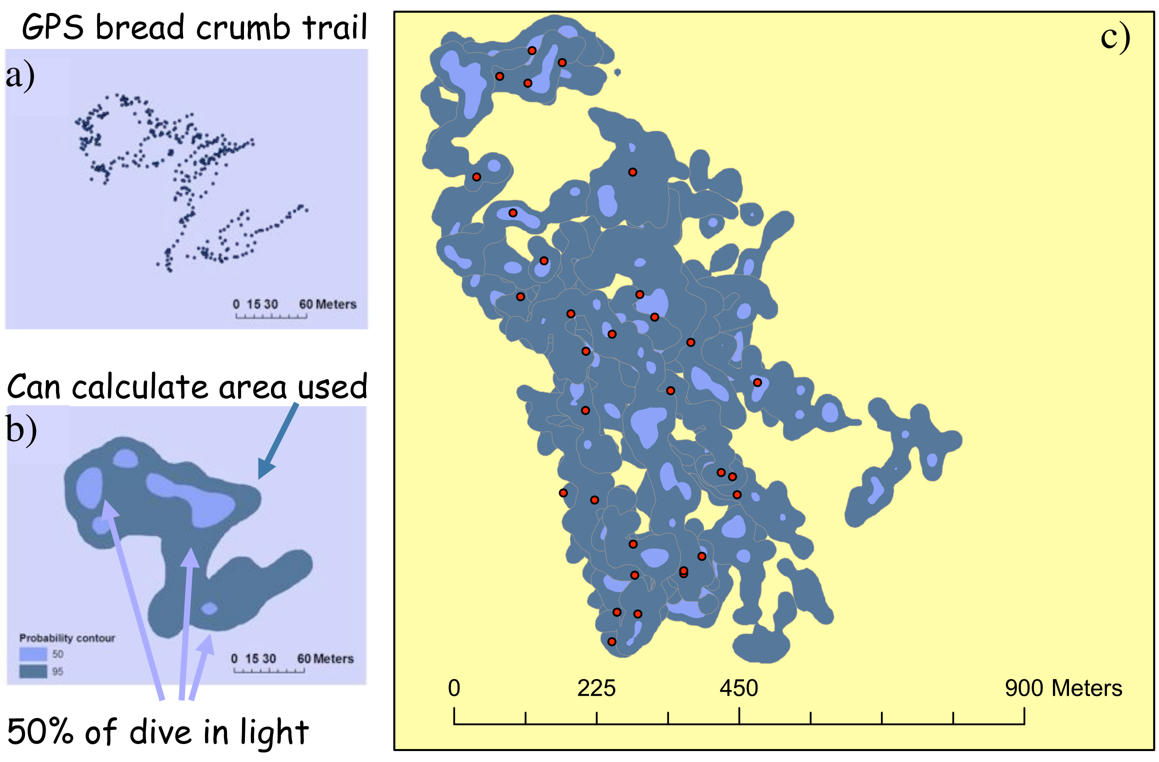

Figure 11: Analyses of GPS track data from fishing vessels using Kernel Density Estimators (KDE) to delineate area utilised. (a) Position coordinates (accurate to 10m) recorded at 10 sec interval points for each dive are used to generate 95% and 50% contour polygons (b) dark blue identifies the 95% utilisation area and light blue 50% utilisation areas i.e 50% of the dive was

spent in this area. Location and overlap of sequential dives for a single diver in one reporting block over 15 months (c) enable analysis of fleet and diver dynamics.
In addition to a location, by recording coordinates every 10 sec we can identify in 2D the area or segment of reef traversed by the catcher vessel. Using GIS software we can calculate the potential area in Hectares of each dive event. Traditional CPUE - kg/hr cannot capture the changes in the area of reef utilized during each dive as stock abundance changes. Alternative parameters such as kg/ha (Figure 12) can provide additional measures of fishery performance. When catch rate was high (> 90 kg/hr), the diver in this example was covering about 1.2 Ha/Hr. At catch rates lower than 90kg/hr (the shaded area) the diver searched increasingly more area per hour as catch rates declined.

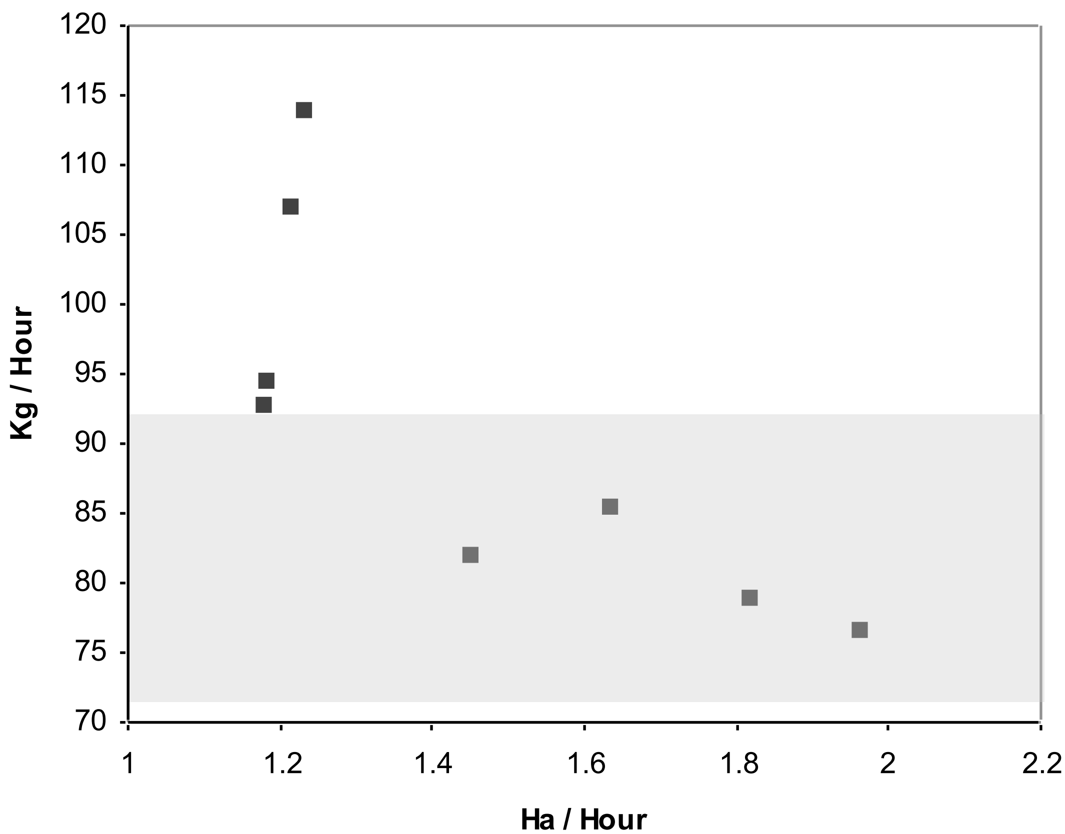

Figure 12: The relationship between traditional CPUE (kg/hr) and a new variable kg/ha.

Mapping fishing effort and catch at fine spatial scales
If the location, catch and effort of each dive event is recorded electronically using GPS and depth loggers, then the spatial scale of assessment can be optimised for different regions. In Figure 13, a 500 x 500m grid was imposed on the same dataset used for Figure 11. Effort was summed within each cell, and even at this scale there is clear spatial structure in effort. In Figure 14, a 100m x 100m cell grid is imposed, that clearly identifies two failings in the 500m x 500m grid. Firstly, that there is a cell of intense effort in the south of the area that is lost at the 500m scale. Secondly, there is a single cell of intense effort in the north of the plot which clearly influences the classification at the 500m cell, despite being surrounded by low or no effort cells.

The electronic approach and the ease of re-processing data means that the scale of assessment is driven by need, and not limited by the scale at which data was reported. For example a 1km x 1km grid may be identified as an appropriate scale to report/assess a region in 2007. In 2010, with contraction in the fishery evident, a 100m x 100m cell grid may be required to identify that contraction and importantly, quantify that change. With high resolution spatial data for each catch event, the region of concern could be reprocessed at the smaller scale, and the contraction easily quantified. Without it, we will be left to speculate whether there has or has not been a change?

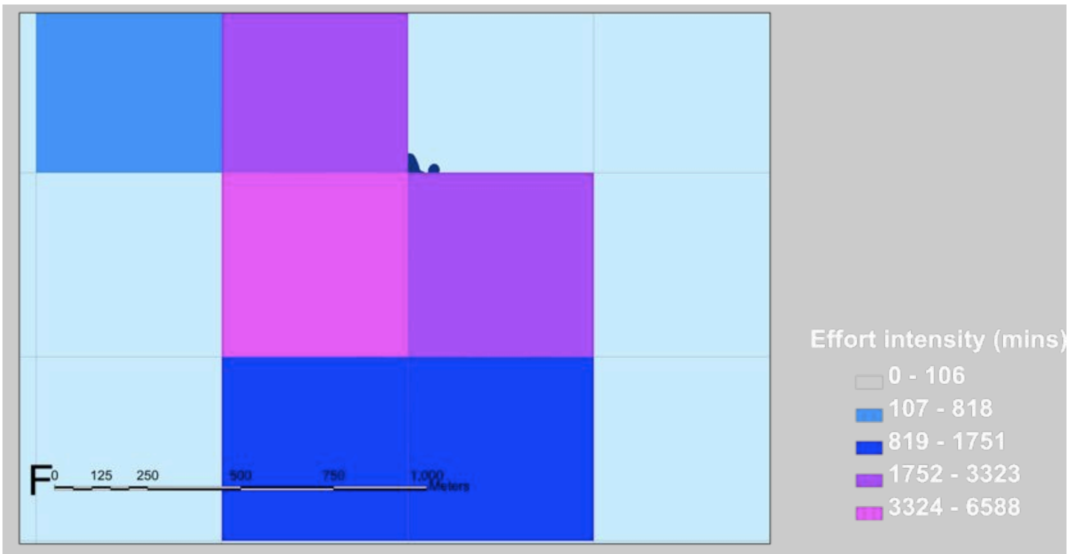

Figure 13: Mapping of fishing effort at small spatial scales – 500m x 500m cell size. Using GIS software the count of all points within each cell on a pre-defined grid, can be quantified. The number of points (each point = 10 seconds of effort) in each cell can be calculated.

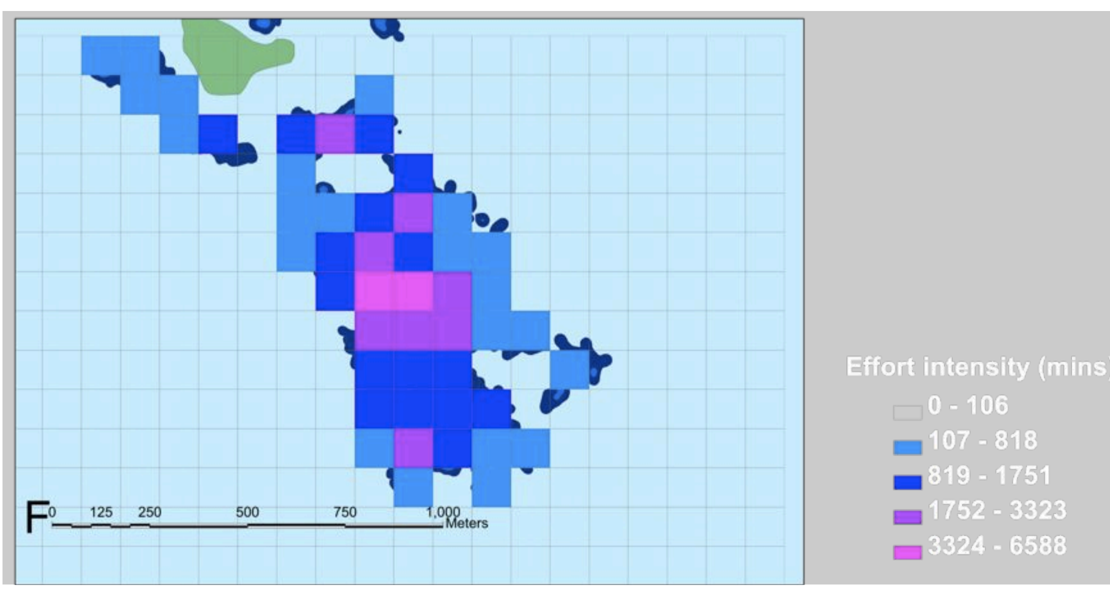

Figure 14: Mapping of fishing effort at small spatial scales – 100m x 100m cell size. An additional benefit of the electronic data collection approach is the ability to re-process data at an alternative grid scale as required.

Cost effectiveness

Electronic data collection can be very cost effective. For example, the cost of Fishery Independent abundance surveys, with a single annual visit to 200 sites would cost in excess of A $400,000 each year, but only cover part of the fishery. For the Tasmanian abalone fishery, this would be an insufficient number of sites to use as the basis of a stock assessment, but also unaffordable, and highly dependent on availability of weather to provide repeat surveys in subsequent years.

Using electronic data collection, hardware to monitor the entire fishing fleet could be purchased for approximately $100,000 with a useable life of approximately 4 years (failure or loss of loggers). Re-training or appointment of staff with GIS analytical skills could be achieved for approximately $80,000, cover the entire fishery, and provide additional benefits for both assessment, management, and research.

Conclusion

Spatial management is an essential component of all fisheries – one need only attempt to find a fishery that is not spatially or spatio/temporally structured.

We began with the observation that Fishery Independent data is needed to validate Fishery Dependent data, and it is fair to say that this information is not interchangeable. However, modern technology has enabled us to combine the best elements of both Fishery Independent and Fishery Dependent data collection. As Fishery Independent data are expensive and often difficult to obtain, the ability to use Fishery Dependent data to prioritise and provide specific locations to collect Fishery Independent data provides a more effective solution.

The practical application of this approach has seen the collection of large amounts of data at a significantly finer scale in both the Tasmanian Scallop and Abalone fisheries. This data is enabling or will enable management at a much finer scale, one that is relevant to the spatial and temporal biological and socio-economic structure of the fishery.

A pragmatic approach is required to identifying the scale at which the fishery is managed. This will most likely involve a hierarchical approach high level control by management at large scales (e.g zonal TAC, size limits), and flexibility of fishing at a smaller spatial scales managed by monitoring of fishery performance with indicator variables and the ability to close sub-sections of the fishery according to objective decision rules.

Importantly, early identification of change in area fished/hr when stocks are increasing will assist with timely adjustment of TAC upwards.

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Building a system of riverine protected areas across the Murray-Darling Basin

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Abstract
This presentation provided an overview of the report *River Parks: Building a system of 'Habitat Management Areas' across the Murray-Darling. An international and national review of freshwater 'protected areas' for conserving aquatic biodiversity and river health.* (by Bill Phillips and Rhonda Butcher, Publication No. 07/06.), as commissioned by the MDBC in 2005. It also outlined progress to date with follow-up work to assemble a GIS of 'river parks' across the Basin, and to assemble a 'toolkit'; both of which are designed to assist practitioners.

The 2005 study identified many opportunities, and some impediments, to the establishment of a Habitat Management Area (HMA) system across the Basin. These opportunities and impediments are found at a range of levels, and across sectors; political, institutional, stakeholder, community and scientific. The strategy put forward in the report was designed to move this issue from the 'too hard basket' into the mainstream of river management for the Basin.

The 2005 report coined the term 'river parks' as a short-hand form for HMA or riverine 'protected areas'; the latter term being used in its broadest sense (across all categories specified by the World Conservation Union – IUCN). The report highlighted that there are at present several tools available immediately for advancing the systematic development of a 'river parks' network for the Basin. These include Ramsar site or Biosphere reserves listings, heritage rivers, fish habitat reserves, State parks and reserves to protect biodiversity, through to demonstration reaches as championed by the *Native Fish Strategy* of the Basin. Despite these opportunities, there is no strategic framework or cohesive effort in place at present to see these various tools working toward establishment of a 'river parks' system.

Among the recommendations from the 2005 report which the MDBC has acted on are the development of an easy-to-use 'toolkit' spelling out how the various opportunities for advancing the 'river parks' agenda can be applied; their pluses and minuses etc. This 'toolkit' is soon to be subjected to review prior to finalisation.

The second part of this follow-up work is the drawing together into one GIS system of spatial information about the current state of affairs with respect to 'river parks' across the Basin. This aims to cover the following (where they contain aquatic elements) Ramsar-listed wetlands, sites in the *Directory of Important Wetlands*; World heritage sites; sites on the register of the national estate, Biosphere reserves, sites of known importance to migratory waterbirds, Indigenous protected areas, sites listed under the EPBC Act as threatened ecological communities or where listed (aquatic) species are found, sites recognised under State or ACT (biodiversity) legislation,

State/ACT parks and reserves of all forms, wild or heritage-listed rivers, areas/reserves declared under State fisheries legislation and demonstration reaches. Once this GIS is assembled the intention is to document the current 'river parks' estate of the Basin and then seek to identify key gaps for priority attention.

The report River Parks: Building a system of 'Habitat Management Areas' across the Murray-Darling. An international and national review of freshwater 'protected areas' for conserving aquatic biodiversity and river health. (by Bill Phillips and Rhonda Butcher, Publication No. 07/06.)

The following is an edited extract from the above report.

Mandate, rationale and key issues considered

This report was commissioned by the Murray-Darling Basin Commission to explore the concept of establishing a system of Habitat Management Areas (HMA) across the Basin, as advocated through the *Native Fish Strategy 2003-2013* (MDBC, 2003). It examines international and national experiences in this field, the science needed to underpin the establishment of such a network, the management prescriptions and approaches needed, and the policy and administrative practicalities of doing this across the Murray-Darling Basin. Using the conclusions drawn from these reviews and analyses, a practical and realistic strategy for going forward is proposed that recognises the critically important issue of gaining community and stakeholder support and engagement in the process.

The study has identified many opportunities and some impediments, both potential and real, to the establishment of the proposed HMA system across the Basin. These opportunities and impediments occur at a range of levels, and within several sectors of society: political, institutional, stakeholder, community and scientific. Each opportunity and impediment needs to be well understood and addressed in the plan for going forward. The strategy for doing this, as set out in section 7 of the report, examines each of these levels or sectors, considers the opportunities and impediments that exist for each, and recommends the actions needed to move this issue from the 'too hard basket' into the mainstream of river management for the Basin.

A 'river parks' initiative for the Basin

The report acknowledges the need to carefully 'market' the HMA concept and to undertake strategic consultations with primary stakeholders, both government and community, to build support and address any misgivings or concerns. It is recommended that the initiative adopt the name of 'river parks' (rather than HMAs) to assist with promoting the concept, and, to provide an umbrella for using the existing array of options available through international instruments, national and State/ACT and local level programs and legislation in a coordinated way for seeing appropriate areas added to the network of sites.

The proposed vision for the system of river parks of the Murray-Darling Basin is:

> **"A network of riverine and floodplain sites that work collectively to maintain biological, social and cultural values and improve river health across the Murray-Darling Basin."**

Multiple-benefits to be delivered by 'river parks'

Significantly, the vision (above) promotes the idea that river parks are established for a range of outcomes, not only for biodiversity, or even native fish, conservation. The review of theory and international and national experiences in this field chose to focus on three different levels of approach to designing a river parks systems (See Figure 1 below); namely, a species-based, aquatic biodiversity-based or ecosystem services-based approach.

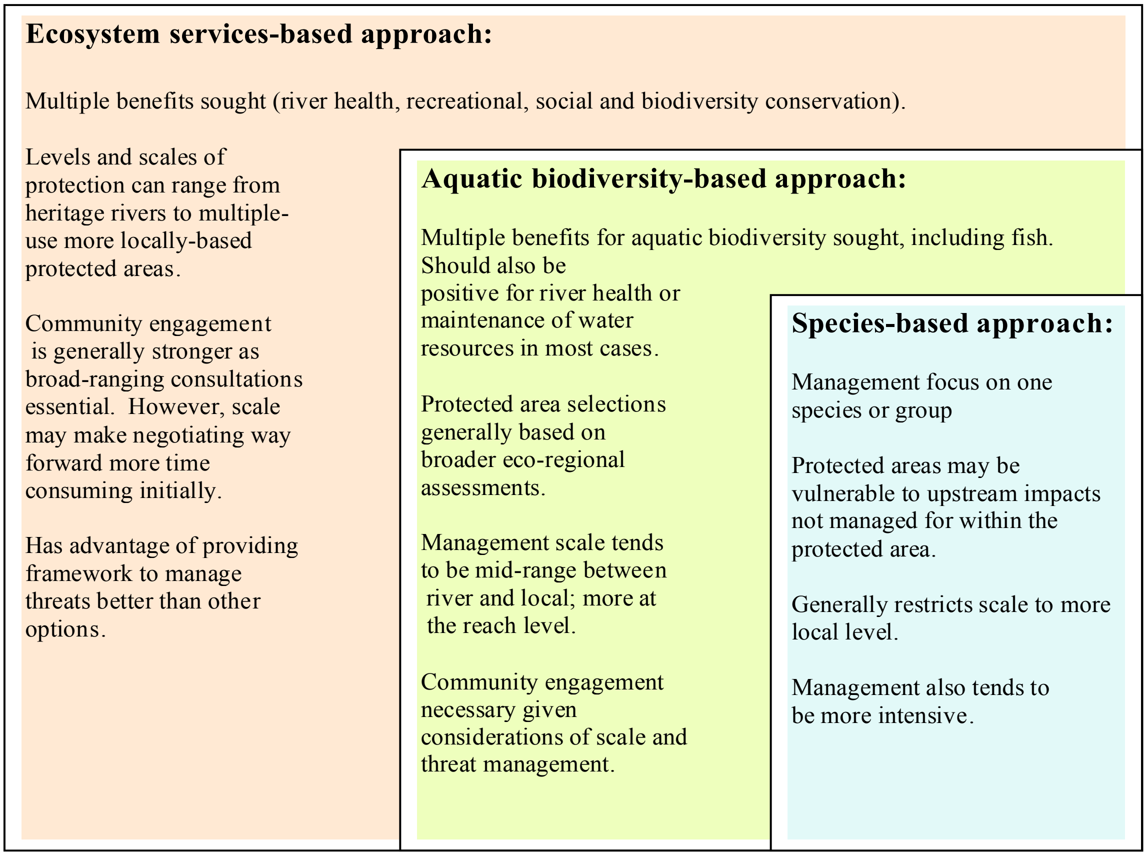

Figure 1: Hierarchy of possible approaches to identifying aquatic protected areas across the Murray-Darling Basin

In summary, the species-based approach is seen to have weaknesses, primarily among these being that it usually leads to relatively localised protected areas that are then vulnerable to upstream or lateral impacts from the adjoining landscape. While it may be possible to select critical habitats for inclusion in protected areas for certain species, (waterbird or fish breeding sites for example) the scale of management still needs to be at the level of river valley or catchment to ensure the continuing viability of the river park and its target species or group. Despite this, it is acknowledged that the species-focused approach can, under some circumstances (such as with icon species like Murray Cod for example), be advantageous in getting community 'buy in'.

Ecosystem or ecoregional-level approaches for selecting protected areas to conserve aquatic biodiversity are generally preferred by most scientists working in this field, although clearly there are opportunities to combine this approach with the more species-based approaches. Equally, the opportunity exists for combining these two approaches with the higher level concept of selecting rivers, reaches or wetlands for river parks that help with improving river health and delivering ecosystem services more broadly (see Figure 1 above). The danger with single species or ecosystem level processes is that these other services (social, cultural and economic) may be compromised or threatened; thus alienating stakeholders. From the perspective of gaining community support and engagement, the approach of using ecosystem services as the primary driver for site selection is more likely to succeed.

Multiple-use management model

There are a range of management options and models available for possible use under the proposed river parks system. These are in part determined by scale and management outcomes. They range (see Table 1 below) from highly regulatory, mostly government-driven management approaches directed at maintaining the naturalness of rivers, or more localised protected area management, focused on threatened species, ecological communities, fish spawning areas etc, through to much more strongly stakeholder-based efforts directed at improving river health. In between, there exist opportunities to apply a range of management models that can (through zoning approaches for example) incorporate some elements of strict regulation or intensive management with the broader scale ambition of seeing river health and ecosystem services rehabilitated.

It is suggested that the wise path to take with development of a system of river parks across the Basin is to make river valleys or catchments the planning level, and to indicate a preference for Canada's Heritage River-type approach as the primary management model. This does not preclude the establishment of more localised river parks within this broad scale framework to respond to specific management needs (threatened species, ecological communities, etc) where they arise. There are clear advantages of these being integrated into broader scale rehabilitation and management efforts, not the least of which is to manage risks and threats better.

The key aspects of the Canadian heritage rivers model that are worthy of note here are that:

(a) it is non-legislative at the Basin scale, although jurisdictions within the Basin may choose to use their legislation for special needs situations. This has direct parallels with situation of the Murray-Darling Basin;

(b) it is a partnership program involving all tiers of government and local stakeholders. This is seen as more likely to succeed in the Murray-Darling Basin than approaches that are 'top-down', or perhaps perceived to be 'top down'. It is also seen as being a highly cost-effective approach; and,

(c) it is not solely directed at biodiversity conservation, although this is a key consideration. Through consultation among the partners, balanced outcomes have arrived that have broader support among stakeholders.

It is also important to stress that the model presented by the Canadian Heritage Rivers system can readily accommodate management approaches. These are described in the report for Biosphere Reserves and Ramsar wetlands and community-level river management and rehabilitation initiatives such as the River Tender initiative in Victoria and the Bidgee Banks project in the ACT and south-east NSW. These are essentially based on the same concepts of multiple use.

Creating a river parks 'tool box'

This report presents a summary of the various international, national and State/ACT government and regional level mandates and tools that are in place for advancing a system of river parks across the Basin. Fifteen are identified (see Table 2) that are potentially applicable, yet it is concluded that to date, they have not been used with great vigour or effect. There appears to be considerable institutional inertia in this area.

Table 1: Range of management options available for aquatic protected areas

Type of management	Management outcome sought	Usual scale of protected area	Typical management prescription	Community-stakeholder roles in management
Strict protection				
	Maintaining 'wilderness' values	Whole river, tributary or long river reach	Human uses carefully regulated, impoundments precluded, water diversions precluded or capped at low level.	Usually little, due to highly regulated management by government agency
	Maintaining critically endangered species or ecological community	Localised to critical habitats	Human uses carefully regulated or even restricted under some circumstances or times of the year	Usually little, due to highly regulated management by government agency
	Fisheries improvement or security	Localised to spawning, nursery or other critical habitat areas in general	May include 'no go' or 'no take' areas or seasons or more cooperative management approaches	Depends on level of regulation.
	Maintaining unique or representative ecosystems, species (and cultural heritage values)	Tributary or river reach, or localised depending on the scale of the ecosystem	Either through national park, nature reserve or more multiple-use management regime. Impacts managed or regulated as necessary through planning.	Depends on type of protected areas. For national parks and nature reserves there is usually little direct involvement. For more multiple-use sites, community and stakeholder involvement can be quite high.
	Maintaining 'heritage' river values	Whole river, tributary or river reach	Human uses managed through plan of management developed in consultation with stakeholders, impoundments precluded, water diversions minimised or capped at low level	Can be quite high depending upon location.
	Maintaining, rehabilitating river health, ecosystem services	River reach or localised	Multiple-uses permitted, although impacts minimised through cooperation and planning	Strong community engagement and ownership is necessary.
Multiple-use				

Table 2: Options in the river parks 'toolbox'

International status 'river parks'	National-State-ACT status 'river parks'*
Listing of sites as Wetlands of International Importance under the Ramsar Convention	**Nomination of freshwater taxa or ecological communities under the Commonwealth *EPBC Act 1999* and related State-ACT legislation**
Declaration of Biosphere Reserves under the UNESCO Man and the Biosphere program	**Addition of river parks to Australia's National Reserve System (NRS) using appropriate State-Territory legislation**
Inclusion of sites on the East Asian-Australasian Shorebird Network	**Declaration of riverine indigenous Protected Areas (IPAs)**
Nomination of sites as possible World Heritage properties	**Declaration of reserves under fisheries legislation**
	Declarations under wild, scenic and heritage rivers legislation

Comments
A Directory of Important Wetlands of Australia provides an established process for identifying potential sites, although has not focused on fish habitats as yet. River reaches could be listed through this mechanism.
No systematic process for identifying possible candidate sites at present. *A Directory of Important Wetlands of Australia* (see at left) may assist.
Relatively few of these areas would qualify across the Basin.
Unlikely to be an option given serious consideration in the short-medium term (see section 5.1.3)
Formal recognition of threatened taxa and ecological communities normally triggers the preparation of a recovery plan, or similar. The latter should ideally consider critical habitat areas.
The NRS has recognised the need to focus more on freshwater ecosystems. The ongoing acquisitions to build the NRS could be encouraged to favour important habitats pending further scientific work to guide future acquisitions.
IPAs give Indigenous groups the opportunity to join the river parks initiative.
Yet to be exercised in the freshwater realm, although offering significant potential to see critical fish habitats protected. Should strive to work with other tools (Ramsar for example) to see options maximised.
There is some progress on this front in both NSW and Victoria, although this is very slow. Not expected that a large number of sites will qualify within the Basin.
Criteria
There are 8 criteria (see Appendix B) although a site needs only to qualify against one. Includes two criteria specifically relating to fish habitat values.
There are five criteria that emphasise the management model of Biosphere Reserves; namely, sustainable development, zoning etc.
Candidate sites are known through Watkins (1993). There are some overlaps with the Ramsar site criteria and those of the *Directory* project.
Need to be able to justify as a 'jewel in the crown' type area. Sites of cultural significance can also be listed.
Criteria for qualification vary depending on jurisdiction.
Aims to have a comprehensive, adequate and representative system of protected areas. No criteria specific to freshwater areas.
Has similar aspirations to the NRS (see at left).
Criteria for qualification vary depending on jurisdiction.
Applies only to Victoria and NSW at present through their respective legislation.

* areas listed under this category may also be internationally listed.

It is recommended that these 15 options be drawn together to form a river parks 'toolbox' of essentially nine elements (see Table 2); four of these relating to significant areas being recognised under international conventions, agreements or associated programs while five are options that currently exist and could be used at the national-State/ACT level. For this to occur, direction will be needed from a suite of natural resource management (NRM) Ministers from the respective jurisdictions of the Basin.

Mobilising the catchment management bodies to take this agenda forward

A key element of the strategy for developing and rolling out the river parks system across the Basin is the role of regional NRM and catchment bodies. These bodies will need to have a primary role in seeing the system developed and then managed. They are therefore primary stakeholders in the development phase, deserving earliest consultation in the process. Another key consideration is that the Commonwealth and States/ACT will need to endorse the river parks initiative as a priority for attention through the NRM program.

Catalysing local actions

It is important that the river parks initiative not be defined, designed, described or perceived as a 'top-down' driven program. For this initiative to be accepted and supported by the broader community it must be able to accommodate, foster and encourage grass-roots driven initiatives as well. Above, it was noted, that regional NRM and catchment bodies have an important role to play in encouraging such local level actions, as do local governments, community organisations and conservation NGOs.

Getting started

The report also proposes options on how to initiate the river parks initiative in the short-term, and proposes (among a range of actions) the following:

> (a) Undertake an audit of established protected areas across the Basin that include aquatic elements and seek agreement from the Basin States and the ACT for these to be the foundation of the Basin's River Parks system, thus 'kick starting' the Basin-wide initiative;
>
> (b) Seek to replicate the *Living Murray Initiative* for the Darling and its tributaries, using Ramsar sites, *Directory of Important Wetlands sites*, or perhaps those sites identified in MDBCs 1998 *Floodplain Wetlands Management Strategy* as the nucleus sites for the development of a series of river parks management zones; and,
>
> (c) Seek out potential local champions, and established river rehabilitation initiatives, to take on a local leadership role with the development of a series of river parks management zones.

The report details a step-by-step strategy for advancing the river parks initiative.

Spatial management in Commonwealth fisheries – are we losing the plot or finding common ground?

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Introduction

Spatial management in a fisheries context is the placing of area-based restrictions on fishing on either a permanent or temporary basis. Spatial or temporal closures are the most common form of spatial management applied in fisheries. The purpose of closures is generally to protect one or more species and/or their supporting habitat. While these are not new, having been used since fishing commenced several thousand years ago, they have considerable prominence in the last decade as part of the on-going debate of which is the best mix of targets and instruments to use when managing wild fisheries.

Spatial management is a common planning tool in terrestrial and coastal environments, but a relatively recent entrant to offshore fisheries management. The last 30 years has seen them used in off-shore fisheries to define the following: the exclusive economic zone of a nation; the area of jurisdiction of regional fisheries management organisations; the area of a domestic fishery; and temporal or permanent closures within a fishery.

There have been many claims made about the use and misuse of spatial management in fisheries, in particular how they contribute to a sustainable fisheries management framework and how they have impacted on the fishing rights of the commercial fishing industry. This paper considers these and related matters in relation to Australia's Commonwealth managed fisheries.

The Fisheries

Several Commonwealth fisheries are considered:

- the Northern Prawn Fishery (NPF)
- the Southern and Eastern Scalefish and Shark Fishery (SESSF)
- the Eastern Tuna and Billfish Fishery (ETBF)
- the Heard Island and McDonald Island Fishery (HIMI).

Each has a somewhat unique history and each illustrates how spatial management plays a key role in ensuring sustainable fishing and the relatively modest impact on the fleet's ability to harvest fish.

The Northern Prawn Fishery

The NPF is a prawn trawl fishery adjacent to northern Australia from west of Cape York to the Joseph Bonaparte Gulf, including the Gulf of Carpentaria. The NPF is a relatively stable fishery in that the key species in the fishery (tiger and banana prawns) have been the mainstay for decades and the status of these resources over that time has for the most part been sustainable. 'Input' controls are used to control effort in the fishery through gear limitation (measured by headrope length), however the fishery is currently developing arrangements to move to 'output' controls in the form of a Total Allowable Catch (TAC)/Individual Transferable Quota (ITQ) system.

Spatial management through both permanent and seasonal closures has been a key part of management for this fishery since the 1980's. Closures are primarily in place to protect juvenile prawns and brood stocks, or reduce bycatch of other prawn species. The industry supports these closures as a means of ensuring good recruitment of prawns to the fishery each season and maintaining healthy prawns stocks.

More recently the industry has requested the Department of Environment and Water to consider fisheries spatial closures for inclusion in meeting Bioregional Marine Planning (BMP) and Marine Protected Area (MPA) requirements for the Northern bioregion. The move to output controls may alter the industry's views on at least some of the spatial management arrangements in the NPF as they may be regarded as superfluous.

The Southern and Eastern Scalefish and Shark Fishery

The SESSF is a mixed gear demersal fishery, consisting of otter trawl, Danish (Scottish) seine, gillnet and line fishing. It stretches from northern NSW, south around Tasmania to southern Western Australia. It is an 'output' control fishery primarily managed through TACs and ITQs. The SESSF virtually has a 100 year history and has changed considerably during that time, particularly over the past 20 years. Originally a shelf fishery, which commenced in 1915, the upper slope and mid slope were developed from the 1970s to the early 1990s. The deepwater fishery commenced in the 1980's with the discovery of large orange roughy stocks, and was a catalyst for the expansion to other fish species as the fisheries capacity to fish the deepwater increased. The deeper water species such as orange roughy, oreo dories and gulper sharks have proven to be long lived, slow growing and/or low productivity, and therefore highly susceptible to overfishing. As a result, the deepwater fishery is effectively being closed from 2007 to enable stocks to recover.

Up until the mid 1990s there was little spatial management in the SESSF. The Great Australian Bight MPA and the fishing industry voluntary closure of seamounts south of Tasmania (later made permanent) were the first two significant spatial management arrangements in the fishery. Since 2000 there has been a flurry of closures:

- southern shark fishery coastal closures for pupping
- fishing industry voluntary closures for ling spawning
- gulper shark closures
- deepwater closures (> 700/750m, all methods)
- Bass Strait trawl closed areas
- SE MPA network.

The fishing industry has been concerned about the progressive spatial restrictions on fishing activity that have resulted from these closures. While the reasons for this are not always clear they probably stem from the rapid and recent changes in the nature of rights they hold, from annual gear based Commonwealth Fishing Boat Licences or fishing permits to species specific catch quotas. Despite industry concern there is no evidence that the gross value of production of the fishery has been negatively impacted by spatial management. TAC reductions to curb overfishing have been the main cause for a declining gross value of production.

Eastern Tuna and Billfish Fishery

The ETBF is a pelagic longline and 'minor' line fishery extending from Cape York in the north to Tasmania in the south. The key target species are tuna (yellowfin, albacore and bigeye) and billfish (broadbill swordfish and striped marlin). It is an 'input' controlled fishery with gear restrictions. The ETBF has had a roller coaster history over the past 20 years. Japanese long-liners dominated the fishery until the mid 1990s when the bilateral agreement ceased. This was followed by rapid expansion of the domestic fleet based on broadbill swordfish, extending eastward through the Australian Fishing Zone on to the high seas. In 2001 the broadbill fishery value and catch peaked and subsequently declined. In the last two years there has been an equally rapid expansion of albacore fishing.

Spatial management has been used in the ETBF for many years to limit fishing effort through establishing specific fishing areas based on historical fishing patterns, but this has been overlaid with a range of new measures since 1998:

- the Threat Abatement Plan (1&2) boundaries for seabird protection
- TAC boundaries for swordfish and albacore
- Seasonal southern bluefin tuna (SBT) boundaries.

Most recently the Government has proposed a spatial closure to separate recreational and commercial fishing along the east coast of Australia. While the fishing industry has accepted the need for spatial management it has done so reluctantly as it has added significantly to the costs of managing the fishery and accessing areas of the fishery.

Heard and McDonald Islands Fishery

The HIMI Fishery is a demersal trawl and longline fishery which has developed since the mid 1990s. Its target species are Patagonian toothfish and mackerel icefish. The fishery is primarily managed through output controls and in keeping with an international agreement (the Convention on the Conservation of Antarctic Marine Living Resources). As a young fishery, it has developed concurrently with MPAs around HIMI and with the benefit of the latest fishery science. Industry has been a direct participant in developing all aspects of fishery management around the islands which has greatly assisted their acceptance. Industry has secure long-term fishing rights which were created around the spatial management measures. Because of this, fishing rights remain unaffected by the spatial management in the fishery.

Fishery Footprints

A common misconception about Commonwealth commercial fisheries is that they have a significant footprint, that is, a large proportion of the area of a fishery has been fished. This error has been used against the fishing industry in support of banning commercial fishing and is largely untrue. For example, the NPF at its greatest extent fishes 17% of the fishery area and the South East Trawl 5%. The vast majority of the fishery area is untouched by fishing gear usually because it physically can't be fished or has no commercially important species in sufficient numbers to make it economically worthwhile.

Another example is the seamounts system south of Tasmania. Originally targeted by orange roughy vessels, seamounts were found to have unique communities and habitats. Claims were made that they had largely been destroyed by the actions of fishing vessels and that urgent spatial protection was required. To its credit, the fishing industry acknowledged this when a large number of seamounts south of Tasmania were voluntarily closed. Over a decade later and with benefit of improved science we now know that a relatively small proportion of these seamounts have been fished and of those that have many, retain large areas undisturbed by trawling.

Discussion

The introduction of spatial measures across Australia's Commonwealth fisheries and more generally around the world has been contentious. A major criticism is that many fishery closures are not adequately monitored to determine whether they are meeting their objectives or not. The primary hurdle of doing so has often been claimed to simply be cost, but the reality has been that until recently our capacity to do so has been limited. This was due to information, technical and policy constraints. The information available on which to establish and monitor has been accrued over many years, however, many areas still remain depauperate leading to claims about the soundness of the spatial management decisions. Many computer-based tools better enable objective optimization of the many variables (and interests) involved. However, this should not discount the valuable expert information not on the record from groups like the fishing industry. Monitoring technologies such as Vessel Monitoring Systems enable real time, accurate monitoring of where vessels are in relation to fishing boundaries, providing a legally enforceable deterrent to fishers to enter closed areas. Finally, policy makers have historically lost interest in fishery closures/MPAs once they are made. While the change is slow there is growing acceptance that the marine environment with its greater assessment uncertainty results in a higher likelihood of (unintended) error in establishing closed areas. This, in turn, places a significant onus on agencies to check that they have got it right.

So what of the future? We are currently witnessing the most significant changes in Commonwealth fisheries management for the past 15 years driven by the implementation of harvest strategies and ecological risk assessments/responses for target species, byproduct, bycatch, habitat and community fishing impacts. Spatial management is one of the response instruments used particularly where sparse information means other tools are difficult to apply and to ensure equal treatment of fishery risks.

A possible 2020 view of the demersal fishing industry is that of one fishing highly productive areas. While this mid-term view may be viewed as constraining, it also presents an opportunity for industry - greater self-management of the resources and supporting environment within these areas. This opportunity arises as the community's interest in Commonwealth fisheries is largely catered through catch quotas, gear controls and spatial management. Consequently, the risk of failure for other stakeholders in industry self-management becomes largely industry's own. The picture is less clear for pelagic fisheries, but already we're seeing the use of spatial management through the government's resource sharing policy for the recreational and commercial sectors in the Western Tuna and Billfish Fishery and Eastern Tuna and Billfish Fishery.

Conclusion

While a question hangs over whether the adequacy of national planning in relation to managing our marine areas, spatial management is currently the instrument of choice when taking a precautionary approach to sustainably manage fisheries and conserving marine biodiversity. In a fisheries context it should be noted this follows a preference for licence limitations in the 1960s, gear controls in the 1970s and quota management in the 1980s. Almost without exception, none had proven to work alone. Recognising this, the 1990s saw a move from focusing on fisheries instruments to outcomes, with Ecologically Sustainable Development (ESD) the most popular outcome sought. In pursuing ESD a combination of well constructed targets and instruments is most likely to lead to sustainable fisheries that benefit the Australian economy. One of these instruments will be spatial management.

Using biological data to select Marine Protected Areas for the oceans around New Zealand

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EXTENDED ABSTRACT ONLY

Introduction

Ongoing declines in global fish stocks, coupled with continuing expansion of fishing into new areas, has raised concerns internationally about the need for a globally representative set of Marine Protected Areas (MPAs) (e.g., Lubchenco *et al.* 2003). Such reserves currently protect less than 1% of the worlds oceans (Wood 2006), a much lower proportion than in terrestrial ecosystems. In New Zealand this concern is reflected in The New Zealand Biodiversity Strategy (Anon. 2000), which specifies as one of its objectives the "protecting (of) 10% of New Zealand's marine environment by 2010 in view of establishing a network of representative protected marine areas". New Zealand MPAs are currently few in number and strongly biased towards inshore waters, with only limited MPAs in waters deeper than 200 m.

Here we demonstrate one approach for designing an MPA network for New Zealand's offshore waters (> 200 m depth), using a combination of recently developed data mining and reserve design tools. We focus on the use of data describing the distributions of demersal fish from approximately 21,000 research trawls, as data for this group of species provides the most spatially comprehensive description of biological patterns in New Zealand's Exclusive Economic Zone. However the method we describe could also be used with distributional data for other functional groups; current research is exploring use of data describing the distributions of benthic invertebrates.

Interpolating species distributions

To overcome the patchy geographic distribution of research trawls, we used environment-based statistical models, fitted using boosted regression trees (BRT) (Friedman *et al.* 2000; Friedman 2002), to interpolate the distributions of 96 demersal fish species. BRT is a relatively novel method in ecology (Leathwick *et al.* 2006), but has its origins in machine learning methods in which a large collection of relatively simple models is used to improved predictive success. BRT provides major advances in predictive performance, and has particular advantages in its automatic fitting of interactions between predictors, and its ability to accommodate missing values in the predictors (Elith, Leathwick and Hastie 2008).

Predictions of species catch per unit effort were made for 1.59 million grid cells, each of 1 km^2 and covering all parts of the EEZ with depths between 200 and 2000 m. Predictors used in fitting these models were environmental factors chosen for their known functional relevance to marine organisms (Leathwick *et al.* 2006). These included the trawl depth, temperature and salinity on the sea floor, tidal currents, chlorophyll-a as a proxy for productivity, and spatial gradients in sea surface temperature to indicate zones of mixing along the sub-tropical front.

Trawl parameters (trawl distance, speed, and codend mesh size) were included to allow correction for variation in these factors.

Two models were fitted for each species using a delta-lognormal approach (Venables and Dichmont 2004). The first was fitted to presence/absence data using all trawls, and the second was fitted to log-transformed catch data from those trawls in which each species occurred. Cross-validation was used to determine the optimal number of individual terms to use in each model, and to estimate performance when predicting to new sites. Cross-validation estimates of predictive performance were verified by also predicting to a completely independent set of 4300 trawls withheld from the model-fitting process. The final models were then used to make separate predictions of probability of catch and amount caught for each of the 96 species for all 1 km^2 grid cells with depths between 200 and 2000 metres. These estimates of probability of catch and amount caught were then combined to form a single predictive layer describing catch per unit effort for each species

Reserve design scenarios

The predicted distribution layers were then analysed using reserve design software (Zonation—Moilanen *et al.* 2005, Moilanen and Kujala 2006) to explore a range of protection options. Zonation differs from most other reserve design algorithms in that outcomes are produced by specifying tradeoffs between the protection of different species, rather than by specifying conservation targets (Moilanen 2007). Its use of high resolution grid data describing the distributions of species made it particular suited for use with our predicted distributions layers. It operates by progressively removing those grid cells whose removal results in the least reduction in overall conservation benefits, gradually building a hierarchy of priorities for protection for all grid cells. In defining these priorities it aims to protect core habitat for all species, including those that occur in species poor areas. Other options allow for the weighting of rare or endemic species, the use of boundary constraints to allow for the negative effects of fragmentation (Moilanen and Wintle 2005), and the use of cost layers to encourage the selection of cells having low costs of protection (Cabeza and Moilanen 2006). Finally, mask layers can be used either to force the early removal of cells that should not be considered as candidates for protection, or to retain selected cells until all other cells have been removed, allowing assessment of the benefits returned by existing or proposed reserves.

We performed three main analyses as follows:

In a **basic** analysis we up-weighted endemic species to insure that they received adequate protection, and applied boundary constraints that recognised that more mobile (mid-water, schooling, and/or semi-pelagic) species are more prone to negative impacts of fragmentation than more solitary and less mobile bottom dwelling species. Protecting the 10% of cells with the highest priority from this analysis would on average protect 27.4% of the geographic range of each species.

In a **cost-constrained** analysis we used the same settings as for the basic analysis, but added a cost layer that we derived from the start locations of approximately 50,000 commercial trawl tows carried out during 2005. A kernel smoother was used to smooth these locations, with values transformed into a range from 0–100 to indicate the average trawl intensity for each grid cell. Although use of this layer resulted in the early removal of cells having high value to fishers, protection of the 10% of cells with the highest conservation priority would still provide average range protection for fish species of 23.4% — fishing would not be reduced under this scenario. This trawl intensity layer was also used to retrospectively assess the cost to fishers of implementing MPAs covering 10% of the EEZ based on the **basic** analysis. Protecting 10% of New Zealand's EEZ based on that analysis would reduce fishing by 21.5%, assuming that fishing could not be relocated to other cells.

Finally, in a **BPA** analysis, we used the mask functions in Zonation to assess both the costs to fishers and the conservation benefits of Benthic Protection Areas (BPAs) currently being implemented at the request of fishers (Ministry of Fisheries 2007). As with the previous analyses, we only considered grid cells of trawlable depth, i.e., less than 2000 m in depth. In this analysis, cells falling within the BPAs were retained until all other cells had been removed. Results indicate that implementing 10% protection of New Zealand's EEZ based on the highest value parts of the BPAs would deliver substantially lower conservation benefits than our cost-constrained scenario (10.4% average species range protection), and would reduce fishing by 0.3%.

Conclusions

Overall our results indicate that there is considerable potential to define MPAs protecting 10% of trawlable parts of New Zealand's EEZ that would have minimal impact on current fishing patterns, while delivering substantially greater conservation benefits than the BPAs currently being implemented at the request of fishers. This provides the potential for genuine win:win decision making in which the differing aspirations of fishers and the broader community could both be achieved to a substantial degree.

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Building the Australian Ocean Data Network (AODN): A one-stop shop for Australian marine science data

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ABSTRACT ONLY

The Australian Ocean Data Network (AODN) will enhance access to, and re-use of, Australian marine science data and data products, by ensuring standards-of-practice across the marine science data management community, and providing a one-stop-shop for marine science data access, using the foundation architecture and services of the Oceans Portal and MEST (Metadata Entry and Search Tool). The AODN offers a single, standards-based, distributed and federated marine science data network. It builds on existing collaborative relationships, agreements, and infrastructure including the existing "Virtual Hosting Repository", which offers archiving, ready discovery and access, and delivery of marine science data from a wide range of funding schemes, and from organisations and individuals in both the government and higher education sector. Two projects of interest are BlueNet and the e-Marine Information Infrastructure Project (eMii). BlueNet is assisting Australian universities to link to the AODN through the development of software, outreach to partner universities and through collaboration with AODN agencies and other virtual repositories (e.g. OBIS). eMii is the data management component of the IMOS (Integrated Marine Observing System) program. Using an integrated standards-based approach across a range of marine science disciplines will, for the first time, drive a new generation of approaches to data management and sustainability.

The pros and cons of Marine Protected Areas in New South Wales: Who's been hoodwinked?

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Foreword

Obviously I think somebody has been hoodwinked! I will return to the question of who, later. But first let me digress from the topic of today and reflect on the concluding comments of an address on trawl fisheries assessments that I gave in 1991 to a conference in Canberra.

In the foreword to his book, *The log from the Sea of Cortez*, the famous American author, John Steinbeck recounted the description his dear friend Doc, a fish biologist, gave of his father, who was also a biologist: Doc stated, 'He is always wrong. If a man makes a million decisions and judgments at random, it is perhaps mathematically tenable to suppose that he will be right half the time and wrong half the time. But you take my father- he is wrong all the time about everything. That is not a matter of luck but of selection. That requires genius.'(Steinbeck 1958). The degree to which Doc's father's powers are attributable to being a fish biologist is something we fish biologists might ponder.

The Pros and Cons of Marine Protected Areas (MPAs)

Worldwide there has been much debate on MPAs, with an emerging consensus that under the right conditions well designed MPAs can be effective tools for conserving biodiversity and assisting with fisheries management, particularly for relatively sedentary species and stable habitats, especially those associated with rocky reefs. There is not such good consensus on exactly what benefits users of MPAs can actually anticipate. Benefits, have unfortunately, been more often assumed than proven, particularly for mobile species and complex ecosystems. Benefits appear to vary greatly from place to place and to be circumstance specific. Very little is said about the problems with MPAs. It would be lovely if there weren't any.

Today I will concentrate on one area and circumstance; the Batemans Marine Park, one of the most recent in Australia, and use it as an example that has relevance to the rest of New South Wales, and possibly Australia more generally. I will take advantage of today's audience that shares an interest in fish biology, to delve in some detail into the science that has been used to underpin the declaration of the Batemans Park. This is in keeping with the vision for research and monitoring by the NSW Marine Parks Authority (the controlling body for the Batemans Marine Park), that the "locations and boundaries for marine parks and the zoning arrangements will have been derived from thorough scientific assessments of all available information and data" (http://www.mpa.nsw.gov.au).

As a starting point for consideration of the pros and cons of the Batemans Marine Park, I refer to a number of documents from the NSW Marine Parks Authority website, (www.mpa.nsw.gov.au), that relate to the assessment of the benefits of MPAs. There are many references by the Marine Parks Authority to the benefits of marine protected areas, but none to the problems.

In this age of increased political scrutiny and public accountability of government agencies most of us would expect to find some advocacy in the Marine Parks Authority's overview of its core business, such as what might be evident by considering only the benefits of MPAs and not the problems. But, on a subject where sound science is so critical we would hope that subsequent decisions which impact public and environmental wellbeing would be based on objective and thorough research. This expectation is reinforced by the Marine Parks Authority's own assertion that this process will be driven by "thorough scientific assessments of all available information and data". For detail and discussion on the benefits of marine protected areas the Marine Parks Authority, not surprisingly, refers readers to another publication, the "Science Paper".

The actual title of this Science Paper is, "A review of benefits of Marine Protected Areas and related zoning considerations" (Marine Parks Authority New South Wales undated). Here the issue of balance, or lack thereof, begins to emerge; one may well question the objectivity in having "the Science Paper" on MPAs consider only the benefits.

The Science Paper is attributed as, "Prepared on behalf of the Marine Parks Authority Scientific Committee": an attribution which projects the full authorization of the Authority and the scientists therein.

In the Science Paper the objectives of NSW marine parks are stated as,

- "conserve marine biodiversity and maintain ecological processes;
- provide for ecologically-sustainable use, public appreciation, education, understanding and enjoyment of the marine environment."

Few could find exception with these objectives: but the purpose of my presentation today is not to consider asserted objectives, but rather the pros and cons of marine parks that are declared in pursuit of these objectives. More specifically, what science underpins the measures that have been taken in the Batemans Marine Park in pursuit of the stated objectives and what these measures are likely to deliver against these objectives. To do so I will go through the Science Paper section by section. The quotations included in the text below are from the Science Paper, unless otherwise referenced.

The Science Paper's introduction to the "Threats to marine environments" states, "This document highlights some of the key threats to some marine species and their habitats and examines key benefits of marine protected areas in addressing these threats." Five key activities, presumably these threats, are then listed: "coastal development, pollution, agriculture, recreational and commercial fishing, and introduced marine pests". It is noteworthy that fishing is fourth on a list of five key threats. Then, dealing specifically with New South Wales, the Science Paper states, "approximately 60% of coastal wetlands lost or degraded over the last 200 years" and "Increased nutrient levels and turbidity from urban and industrial discharges and catchment usage are the key causes of increased turbidity and nutrient levels that often result in a decline of seagrass habitats and diversity of species in soft-sediment areas". Here I am not trying to draw attention to the repetition, but rather to note that this pivotal listing of key and direct threats to coastal environments, which are reported to have resulted in serious damage to 60% of wetlands, does not include fishing. The Science Paper does, however, subsequently state that, "The overall pressures include some fishing activities". The only specific fishing activity mentioned in the Science Paper is demersal trawling, which is, in this region, an offshore activity. Not a single estuarine or beach fishing activity is identified as being responsible for the identified declines, or even as being a threat.

General statements on fisheries problems around the world are then followed by the somewhat leading comment, "There are a number of species in NSW identified as being at moderate to high risk of becoming overfished; many of which are shark species". This key statement is neither substantiated, nor referenced. What it is actually saying is that there are no species in NSW that are currently overfished. An FOI request on information relating to the proposal for the introduction of the Batemans Marine Park revealed that NSW Department of Primary Industries, the State's fisheries management agency, in its communication with the Marine Parks Authority on the Batemans Marine Park before it was declared, actually listed four fish species it considered as growth-overfished in NSW: snapper (*Pagrus auratus*), silver trevally (*Pseudocaranx dentex*), sea garfish (*Hyporhamphus melanochir*) and kingfish (*Seriola lalandi*). Disregarding this inconsistency between the fisheries management authority, NSW DPI, and the Marine Parks Authority on fisheries management, it is significant that neither agency provides any evidence for any current, or even anticipated problems, with predominantly estuarine or ocean beach species in NSW.

The Science Paper then continues, "The protection of species and their habitat can result in benefits to a range of species and habitats, some of which are documented below."

"Increases in the size and numbers of marine fish and invertebrates in sanctuary zones".
I found it hard to understand the necessity to provide a lengthy explanation of why it is remarkable that there would be more fish and invertebrates in areas that are protected from real threats. Surely if sanctuary zones do actually provide protection from the known threats then, logically, it should follow that unless the purpose of the sanctuary zone is solely to protect some clearly identified critical habitat, such as a spawning or nursery area, then the biomass of at least some of the species being protected in the zone would be higher than it is in areas that are not protected? If not, why have "protected" areas? If we are truly trying to assess benefits, the objective should surely be to assess if having closed areas leads to conservation of biodiversity that would otherwise be lost, or at least seriously threatened, and/or, the normal objectives of fisheries management, maximum or optimum sustainable yield from the total resource, are enhanced by having access to part of the resource restricted. However, as more space in the Science Paper is devoted to the benefits in the form of increased numbers and size, than to any other benefits, obviously the Marine Parks Authority believes this is truly critical. Furthermore, as this is the first example of the Marine Parks Authority documentation providing specific examples, as opposed to unsubstantiated generalizations, these examples warrant consideration. The Science Paper continues:

"Some examples from around the world that document the benefits of sanctuary zones are:" What follow are 13 separate examples given in support of this assertion. Most are referenced to the scientific literature. The first states, "In the De Hoop sanctuary, a surf beach on the southern coast of South Africa, the numbers of 6 surf-zone fish species increased by between 30 and 500% compared to fished beaches". I thought I should check at least some of the referencing in the Science Paper, but without the time to check it all, I was concerned with how to do so without being 'selective'. My conclusion was that an objective place to start would be the first specific example in each section and then, if available, an example from within Australia, preferably New South Wales.

Two references are cited for the above quote on fished beaches, Bennett and Attwood (1991) and (1993). Even if I was somewhat concerned that more recent references could not have been found, I found these two papers to be quite good in a field plagued by imprecision, but I do think they have been overly optimistic in their interpretation of the relationship between angling catch per unit effort (CPUE) and abundance, relative or otherwise. But my purpose here is not to review cited papers, but rather to assess how they have been used to support the creation of the Batemans Marine Park.

The two Bennett and Attwood papers actually refer to the use of angling techniques to assess the effectiveness of closing areas where "the shore is a mixture of sandy beach and aeolianite beach-rock platforms": not a "surf beach" as stated in the Science Paper. The 1991 paper was based on the use of angling CPUE as an indicator of abundance. The 1993 paper concentrates more on the variability in experimental catches. Bennett and Attwood actually studied ten species, not six. CPUEs for only six of these were higher in the closed areas. Of these six species the two most prominent (*Coracinus capensis* and *Diplodus sargus capensis*), which account for more than 90% of Bennett and Attwood's samples, are described in FishBase (04/2007) as reef associated, as is another (*Diplodus cervinus)* of the remaining four. The habitats of two of the other three species (*Sparodon durbanensis* and *Rhabdosargus holubi*) are described in FishBase, respectively, as "mainly off rocky shores" and "over sand between rocks". Only one of the six species (*Lithognathus lithognathus*) has a habitat described as "over sandy substrate". Therefore the results from only one of these six species are truly relevant to evaluation of the effects of closures on sandy areas such as would normally be consistent with "fished beaches".

Of even greater significance to the issue of the relevance of the two cited South African papers to assessment of possible benefits to the Batemans area from the closure of surf-zone beaches is the following quote from Bennett and Attwood (1991), "Only 2 of the 10 species examined in this study, *Argyrosomus hololepidotus* and *Pomatomus saltatrix*, are highly migratory and neither demonstrated any benefits from protection in the reserve". The last two species names may have been familiar to many of you. *Argyrosomus hololepidotus*, actually shares the same species name as our mulloway, and *Pomatomus saltatrix* is the same species as, or an extremely close relative of, our tailor (FishBase 04/2007). Curiously, as it is based on the same data as the 1991 paper, the 1993 Bennett and Attwood paper adds a third species, *Umbrina canariensis*, to this group and states, "The catch rates of the same three species…did not increase following the proclamation of the marine reserve, because they are migratory". Why was this key information not mentioned in the 'Science Paper' presented as a basis for a marine park in the Batemans region, where migratory species dominate? The primary target species on ocean beaches in the Batemans Marine Park, Australian salmon, bream, flathead, mullet, mulloway, tailor and whiting are migratory, even if not all equally so. Incidentally, these same migratory species are dominant in the estuaries of the Batemans region.

It is also relevant to note that two thirds of the Discussion in Bennett and Attwood (1991) is about why there is need for caution in accepting that CPUE in this study actually reflects abundance. The key statement on this in the discussion is, "It is evident that angling CPUE should be interpreted with some caution". There is continuing debate within the international fisheries community on the problems of interpreting CPUE data. Line fisheries pose particular problems, such as apparent learned behaviour, which have proven difficult to explain, let alone quantify. My conclusions from this global debate are that CPUE has its uses as a measure of relative abundance, but its relationship with total abundance is seriously questioned, particularly for recreational line fisheries. Few would argue that angling CPUE is a reliable measure of absolute abundance, such as is expressed by numbers of fish. Thus, the actual conclusions that should be drawn from the two papers cited in the Science Paper are a long way from the inference of "the numbers of 6 surf-zone species increased by between 30 and 500% compared to fished beaches".

The relative size of the protected area in the De Hoop Nature Reserve is also noteworthy. Bennett and Attwood (1991) state, 'The protected area of coastline is 46 km long'. Even a reserve of this size, more than six times longer than any of the beach sanctuary zones in the Batemans Marine Park, had no detectable impact on migratory species that are the same or similar as those that dominate in the Batemans region.

Therefore, the logical conclusion, relevant to the Batemans Marine Park, from these two cited papers, is that the closure of ocean beaches as included in the Batemans Marine Park will have absolutely no demonstrable benefit, even for the CPUE, let alone the numbers, of the important species on the ocean beaches in the region.

Noting the strength and unidirectional nature of the prevailing current off south eastern Australia, the East Australian Current, it is not surprising that the bulk of the species that are not tightly associated with local reefs are even more migratory than in other parts of the world. Even one of our most prominent rock associated species, luderick (*Girella tricuspidata*), is seasonally migratory. Therefore it could be anticipated that area closures would be of even less value as fisheries management tools for the species normally targeted in NSW, than they may be in other parts of the world, such as South Africa.

Then, as mentioned above, I looked in the Science Paper for examples closer to the Batemans region: the Solitary Islands Park being the most relevant area referred to. It should be noted here that the Solitary Islands Park is less than ten years old as a Park, but aquatic reserves, which were in effect fishing closures, were in place since 1991. Therefore after a total of 15 years of prohibiting fishing in sanctuary zones it is reported by the Marine Park Authority's Science Paper that there is evidence that "the abundance and mean size of mud crabs (*Scylla serrata*) were consistently greater within sanctuary zones" and, "there are preliminary indications that certain demersal fish such as red morwong (*Cheilodactylus fuscus*) have greater densities in sanctuary zones, but the patterns are often inconsistent between sites".

While this faint praise could be sufficiently damning for most, I thought I should check the reference (Butcher *et al.* 2002) given for mud crab abundance, as this is the first local example. Butcher *et al*. (2002) actually report a difference in CPUE (the Science Paper states abundance), this time from trapping, in sanctuary and fished areas.

Perhaps more important than just noting the reported CPUE for mud crabs in sanctuary zone of two and a half times that in fished areas, is consideration of what this might mean to the well being of the species and fisheries based on it, and therefore the real benefit from the sanctuary zones. Such analysis is, unfortunately, completely lacking in the Science Paper.

There is clearly need for caution when comparing catch data from different fisheries, particularly those for different species, let alone in different countries as carried out in the Science Paper, but the assertion that relative CPUE data from crustacean trap fisheries are automatic indicators of management success can be investigated to at least some degree by the use of comparisons.

The Western Australian rock lobster fishery is a crustacean trap fishery which enjoys an international reputation for being well managed and extremely well researched. In the most recent paper on the subject of changes in CPUE in this fishery (Wright *et al.* 2006) raw CPUE in one of the key fished areas, Area A, is reported at the end of each season to be less than one sixth of what it is at the beginning of the season. In other words, in one of Australia's best managed fisheries the level of exploitation, as indicated by a drop in raw trap CPUE to less than one sixth, is more than twice that for mud crabs in the fished areas in the Solitary Islands Marine Park, where the difference is to less than half. Therefore, based on the data identified in the Science Paper for the Batemans Marine Park, compared with data from the Western Australian rock lobster fishery, mud crabs in the Solitary Islands Marine Park, are, either considerably underexploited, even in the fished areas of that park, or the sanctuary zones have limited impact on the relative abundance of mud crabs in the park.

Before putting too much weight on a comparison of CPUEs in mud crab and lobster fisheries, the degrees to which the pre-fishing stock levels at the beginning of the sampling periods, and the mobilities of the two species, may impact catch rates and subsequent assessments should be further taken into account. I have not done this and it certainly has not been done in either the Science Paper or the papers it cites. However, it is pertinent to note that the higher mud crab CPUE reported in sanctuary zones in the Solitary Islands Marine Park is based on comparison only between fished and unfished zones of the same estuary. Therefore, it provides no evidence what so ever on the relative health of this estuary compared to other estuaries in the region. Thus it provides no indication that the estuaries in the sanctuary zones of the Solitary Islands Marine Park have received any protection at all from the real threats to them, identified elsewhere in the Science Paper as being, primarily, siltation and pollution.

My above consideration of mud crab CPUE is not intended as a fundamental criticism of the paper by Butcher *et al*. (2002) or that increases in CPUE in sanctuary zones are not good. It merely points out that the assertion in the Science Paper that the Solitary Islands Marine Park is providing valuable conservation and fisheries benefits, as demonstrated by the mud crab paper referenced, should not be accepted. In fact, based on the information given it can be argued that the closure of areas in the Solitary Islands Park to fishing for mud crabs is contrary to the best interests of the wise use, ecologically sustainable development, of this apparently underexploited resource. The documentation also fails to provide any evidence at all that the declaration of sanctuary zones has provided any protection of estuaries from the real threats.

As for red morwong where the suggestions of increases are inconclusive, one can only conclude that it is lightly exploited, and/or that the Solitary Islands Marine Park sanctuary zones, after 15 years, have had little impact on its relative abundance, even though it is a sedentary fish species (described in FishBase as reef associated). Unfortunately this noting of red morwong in the Science Paper is unreferenced so I was unable to look at the data in more detail

As no other local success stories are given in the Science Paper on the benefits of marine protected areas as measured by "increases in size and n umbers of marine fish and invertebrates in sanctuary zones", it must be assumed that mud crabs and morwong are the two outstanding examples to date of the New South Wales experience of the benefits of such management measures. Neither provides the slightest reassurance.

"'Spillover' of fish from sanctuaries into areas open to fishing"

There is a great deal of literature on this subject and the degree to which 'spillover' actually benefits species and fisheries management is hotly debated (see, for example, Botsford *et al.*

2006). Therefore I felt there was little need to discuss this in detail or to review the international references given in the Science Paper.

It is, perhaps, noteworthy that the Australian references are again to mud crabs. This time in the Moreton Bay Marine Park, where the Science Paper reports, mud crabs "were twice as common in sanctuary zones than in fished areas" and "some of these crabs 'spilled over' into fished areas". Similar 'spill over' is reported from the Solitary Islands Marine Park, where the same paper as discussed above (Butcher *et al.* 2002) is referenced.

It should be a given that for all but the most sedentary species there will be some exchange of individuals with surrounding areas and even that it is reasonable to expect some net flow from areas of relatively high abundance. For highly mobile, or migratory, species the reason area management struggles to be of value is because unless closed areas cover the majority of the total distribution of the species, 'spillover' tends to be so great that there is little, if any, benefit from the closure. In other words in many areas, 'spillover' is approximately equal to 'spillunder', or more correctly, 'spillinto'. The real objective should not be just to prove there is flow in one, or even both directions, but to assess if the net shift justifies the management measures that are necessary to facilitate it. The efficiency of management against the stated biodiversity conservation and fisheries management goals is what should be important. Consideration of such issues is completely absent from the Science Paper.

"Sanctuaries lead to improvements in ecosystems and habitats"

The first example referenced here is to a sanctuary zone in New Zealand, the Leigh Marine Reserve. The major statement relevant to improvements in ecosystems quoted in the Science Paper, and attributed to the paper of Babcock *et al*. (1999), is, "The primary production of the marine reserve was estimated to be over 50 times greater than it was before protection from fishing". Such an increase would make any skeptic of the benefits of marine protected areas nervous, and any interested student, or marine park manager, eager to understand it fully so similar increases might be facilitated in other marine reserves. So, as a student, I looked. The actual concluding statement from the section in Babcock *et al.* (1999) on "Primary productivity", is, "Overall, the total primary productivity of the rocky reef habitats we examined increased by 58%". Thus the Science Paper presents an exaggeration by approximately one hundred fold.

No Australian examples are given.

"Improved reproductive potential of key species in sanctuary zones"

The banner statement in this section, "For most marine animals…egg and sperm production increases exponentially with size", is leading, as we are meant to assume that fish will be bigger and more numerous in sanctuary zones, but it is at best, imprecise and inaccurate. Egg and sperm production, within a fish species, in relation to size as measured by weight, is close to linear for many species. For length, the relationship is often a power function, but is normally not strictly exponential, particularly for live-bearers. Marine mammals are "marine animals", and the statement in the Science Paper certainly does not describe their reproductive behaviour. More specifically for the Batemans region, the key species in this area are migratory and no spawning areas have been identified, therefore the assertion that the sanctuary zones as declared in the Batemans Marine Park will provide improved reproductive potential for them is wishful, at best.

"DESIGN CONSIDERATIONS FOR MARINE PARKS"

The first paragraphs under design consideration describe the need for conservation of a "comprehensive, adequate and representative sample of marine biodiversity". This objective appears perfectly reasonable for a series of marine parks in NSW, and without detailed review of the actual work done, a bioregional assessment of areas with important biodiversity values would appear to have considerable merit. What is highly questionable from the information given in the Science Paper is the "ability to manage impacting activities", such that the biodiversity identified as in need of conservation, is actually conserved (protected) and that the prescribed measures represent effective and efficient management.

The Science Paper continues: "Other important design considerations for marine parks include:"

- *"consideration of the marine park location and extent and zoning arrangements in relation to ecological processes (e.g. movement and biology of particular species), distribution of habitats, and practicality of management (e.g. enforcement, education);".* As discussed above, ecological processes such as the movement and biology of particular species, have clearly been ignored. Key links between biology and habitats, such as identification of spawning and nursery areas, have not even been considered. The practicality of management is not discussed at all in the Science Paper.

- *"assessment of the vulnerability of the biodiversity and threatening processes;".* Assuming that this criterion relates to the vulnerability to threatening processes it is appropriate here to note that the actual threats to the biodiversity in the differing types of habitats are not adequately identified and/or addressed. For example, for estuaries two key threats, 'increased nutrient levels and turbidity from urban and industrial discharges and catchment usage', and four additional direct threatening processes, 'introduced marine pests, swing-mooring chains, propellers and retrieval of anchors', are described under "Threats to marine environments". Not one of these identified key threats is addressed at all in the remainder of the documentation.

- *"the ecological sustainable use of marine resources for a range of human activities;".* This constitutes the only mention of Australia's guiding principle of natural resource management, ESD, in the whole paper. No related goals or actions are described and no anticipated, or even desired, outputs or outcomes are even mentioned.

- "*economic, social and cultural selection criteria which are considered in the zoning process;".* As there is a separate Socio Economic Report and an Economic Report provided by the Marine Parks Authority (http://www.mpa.nsw.gov.au), no discussion of these items is necessary in the Science Paper. However, as the Executive Summary of the Socio Economic Report contains key statements that are relevant to several key points in the Science Paper, some discussion here, is warranted. The Executive Summary notes there is likely to be adverse impacts on commercial fishing and "There may also be minor effects on charter boat operators and recreational fishers…However, the economic impact analysis suggests the impact is likely to be small for the region as a whole and partly offset by additional Marine Parks Authority expenditure". The failure of the Batemans Marine Park proposal to take account of the extremely high financial and social cost to a significant number of individual recreational fishers, particularly the elderly, the very young and the financially disadvantaged (poor), who have greatly reduced means of translocating their angling efforts, totally compromises the socio-economic assessments. In cases where life-style reasons, that include proximity to favored or traditional angling spots, have influenced house purchases and relocation of families, these financial costs could run into the hundreds of thousands of dollars for an individual angler. Replacing income from the commercial fishing sector with taxpayer funded expenditure from the Marine Parks Authority, as outlined in the Executive Summary, may balance the score-sheet for the local councils but it will do nothing for the average fish consumer (>90% of the population) or the reputation of local restaurants for using fresh, local produce.

It is also most significant that the Socio-Economic Study lists the positive economic and social impacts from the establishment of the Batemans Marine Park as including, "growth in tourism through marine park management and promotion". Thus the primary beneficiaries of the establishment of the park are acknowledged by the Marine Parks Authority to be those who manage and promote the Park. This group constitutes the marine parks industry.

- "*buy-back of sufficient commercial fishing licences to minimize displacement of commercial fishing from sanctuaries to other areas;"*. It is inappropriate to have a buy-back of licences aimed at minimizing displacement of fishing effort without relevant assessment of what levels actually constitute optimum effort and where that effort is most efficiently employed. No such assessments have been provided. As most of the species taken by commercial fishing in this area are migratory, or at least highly mobile, it is more than possible total kill of these species will not be significantly changed by localized removal of fishing. While the need to compensate commercial fishers who may be disadvantaged is acknowledged, great care must be taken to ensure that effective effort is managed and license-splitting, and other undesirable outcomes from poorly researched and implemented effort reduction schemes, do not occur. Without access to the details of exactly what licences are being bought and what license conditions remain on fishers it is impossible to fully assess the impact of this measure. But it is difficult to imagine how a buy-back of licences in relatively small pockets of the New South Wales coastal fishing grounds could constitute the most efficient use of taxpayers' money, or the most efficient area management in the interests of the optimum ecologically sustainable use of the resource. It appears more likely to create a culture among commercial fishers of holding out for a series of localized buy-back, or compensation, payments at the expense of the most appropriate overall management of the fishery. Fisheries data, such as yield per recruit analyses, that have been available since the early 1990s, show that a closure of all areas inside three miles of the NSW coast to all fish trawling would benefit many fisheries, particularly the fish trawling industry itself. These benefits do not necessarily come from closing small bits of this total area.

A series of "examples of the application of ecological criteria to zone planning" then follows:

- '*One of the key aggregating species that are protected in NSW marine parks is the grey nurse shark'*. The assessment of the grey nurse shark is currently subject to legal challenge so detailed comment here is not appropriate. However, it should be mentioned that, because of the mobility of grey nurse sharks, whatever protection of this species may be represented by the declaration of a series of sanctuary zones up and down the New South Wales coast, this will not, in itself, protect this species.

- *'Studies of some fish species inhabiting rocky reefs in NSW suggest that sanctuary zones of between 2 and 6 km long would be optimal for many temperate species. For example, the average home range of a commonly targeted reef fish (red morwong) is around 1800sq/m. This is an estimate of the minimum area of suitable habitat required in a sanctuary zone for it to provide some protection for this species'*. Again the red morwong becomes the center of attention. Why is it necessary to provide protection for this species? It is neither endangered nor assessed as over-fished. Why would you use the requirements of a minor (red morwong represented 0.02% of the angling catches in the major surveys (Steffe *et al.* 1996) for which data are held by NSW DPI (Steffe, pers comm. 2007)), unthreatened species as the justification for determining the size of sanctuary zones that impact all the major target species? 'The average home range' of red morwong of 1800sq/m actually represents an area approximately 42 metres square, or in the words of one of the authors, Ian Suthers, of the cited paper, Lowry and Suthers 1998, "the size of a tennis court". It is also interesting that this cited reference, actually estimated the daytime home range to be 1865sq/m and the night time range to be twice that, 3639sq/m. However if the assertion, that a home range of 1800sq/m leads to the need for sanctuary zones of between 2 and 6 km long, then this would again confirm that sanctuary zones of the size of those in the Batemans Marine Park have no chance what so ever of representing effective, let alone efficient, management for even one of the many prominent migratory species in this region that have distributions covering hundreds of kilometers. It must also be noted that the distributions of these species vary considerably so the chances of any closure being the primary conservation tool for all, or even the majority of them, is slight, unless such closures cover the majority of the distributions of them all. Such an area would likely have to encompass all marine waters of coastal NSW and possibly much of Victoria and southern Queensland. Fortunately none of the key species has been identified as in need of conservation and, even if they were to be so classified, it is most unlikely area management would represent the most appropriate form of management.

- '*Species with large ranges can receive protection within sanctuaries during specific life-history stages such as juveniles, or at aggregation sites for spawning and/or feeding…when aggregated species are often vulnerable to high catch rates. Such aggregation sites make ideal sanctuary zones as they can protect key locations for many species.'* It is true that sanctuaries can provide protection for critical activities of some species. Protection of gravel beds for spawning trout and salmon is a well documented example. But when the goal is efficient use and management of the species, as intended under ecological sustainable development, then the closure of areas of high catch rates of adults is extremely difficult to justify for any species that is not over-fished or endangered. Even if a species is over-fished, the goal should be to determine a holistic management response that will return stock levels and harvest strategies to optimum. There may be justification for closing a spawning area, particularly for species that have been assessed to be recruitment-over-fished and when the stock-recruitment relationship indicates that this type of management is warranted, and the area is demonstrated to be of special significance. The implication, in the Science Paper, that an area should be closed simply because it is an aggregation site is contrary to optimum efficiency of exploitation. It matters little if the aggregation is for spawning or not, as a dead fish does not spawn: whether it was killed three months or five minutes before it would have spawned is of relatively minor consequence. The world has many well managed fisheries that are based on exploiting spawning aggregations. It is the size of the population that is allowed to spawn that matters. The inference in the Science Paper that good angling areas should be closed simply because they are good angling areas is also worrying in the extreme. Do these key statements indicate more about the real intentions of those who wrote the Science Paper and championed the Park than is otherwise stated?

- *'Placing sanctuary zone boundaries on sand adjacent to rocky reefs is recommended to maximize protection to many reef species that move over the entire reef. For instance, a movement study of six Tasmanian reef fish on a very small (1ha) isolated reef indicated that while they moved around the reef, they tended not to* *move off onto the adjacent sand areas'*. Why would you advocate sanctuary zones on sand adjacent to rocky reefs, and then reference, as your justification, a paper that you report as determining that reef fish "tended not to move off onto the adjacent sand areas"?

- '*Studies of beach species suggests that to effectively provide protection, whole beaches need to be included in single sanctuaries due to movement along the beach'*. This final example of the application of ecological criteria typifies the flawed logic and misrepresentation of the scientific literature that characterize the Science Paper. The two references given to support the above quote are the same two papers by Bennett and Attwood, (1991 and 1993), discussed above. Additional to the fact that neither of these papers is really about beach species, in neither of them can I find any reference what so ever to the need to close whole beaches. There is not even mention of "whole beaches" as the study site is described as a mixture of sandy beach and rock. As discussed above, the rock is of particular importance to the dominant species studied. The logical conclusion from the two papers referenced is that there is no conservation benefit at all for fish from closing sandy beaches as the species found there are likely to be migratory and not responsive to this type of area management. The above quoted statement in the Science Paper, which represents the only justification given for closing whole beaches, appears to me to be total fabrication. I hope others can demonstrate that it is not, for if there is a greater crime in science than manufacturing 'results' it is doing so and then attributing these 'results' to somebody else. Consideration of the broader aspects of the closure of ocean beaches in the Batemans Marine Park to fishing provides further evidence of the fatally flawed and biased logic underpinning this process. As discussed above the key fish species found on the ocean beaches in the Batemans area are migratory and the closure of beaches, as detailed in the zoning plan, will offer no assessed conservation benefit to them. Furthermore, the general ecology, or even invertebrate biodiversity, of these beaches will not be protected by closing them to fishing: waves, swells, currents, tides, winds, siltation and pollution are the primary factors which impact the geomorphology and the underlying ecology of ocean beaches. Of course, alterations to these factors, and sea levels, by increasing climate variability, man induced or not, may well over-ride even current oceanic, climatic and anthropogenic influences. Claiming "protection" of ocean beaches by implementing a fishing closure as detailed in the Batemans Marine Park documentation is total misrepresentation of reality.

The final paragraph under "Design Considerations" makes the key statement that, "The benefits of protection in a marine park for a particular species are related to the extent of threats, the spatial arrangements of their habitat (and therefore the spatial arrangements of zones), and their specific life-history patterns (growth, movement, recruitment, etc)." The threats to estuarine species are briefly outlined in the Science Paper, but none of these key threats is addressed at all. No threats for any beach species have been identified in the documentation and the true threats to beaches have been conveniently neglected. Fish trawling has been identified as a threat to offshore areas but "particular species", or habitats, have not been identified. The relatively offshore species, the grey nurse shark, has been identified as in need of protection, but the wisdom of declaring a marine park that closes fishing to one small part of the southern distribution of a migratory, or at least mobile species, has not been demonstrated.

The "spatial arrangements" of the habitats of the target commercial and recreational species are not even listed. The "life-history patterns (growth, movement, recruitment, etc)" are, all too conveniently, ignored. No growth related assessments, even such as basic yield-per-recruit analyses for different species in different areas, have been carried out: it could be expected such analyses would be a prerequisite for area management measures of the type proposed here. The highly mobile, or migratory, nature of the majority of the key species has been conveniently overlooked. No spawning, or key nursery areas have been identified.

In combination these omissions represent a sad condemnation of a series of documents that fail to address even their own stated design requirements.
The "Conclusion" to the Science Paper again reverts to the generic benefits of marine parks that are simply not addressed in the documentation. From the international literature, there is indeed "considerable scientific information that indicates that the designation of zones in marine parks that provide protection from impacting activities is an important tool in the long-term management of marine resources". As there is merit in the introductory statement on the Marine Parks Authority website that, "Internationally, there is support for well designed marine protected areas". The key words here are "well designed" and "protected".

The primary criteria for well designed protection begin with clear identification of exactly what it is that is being protected and what it is that it is being protected from. Then what should follow is logical explanation of how the proposed management measures will provide the necessary protection, and why these measures represent the most efficient way of doing so. Not one of these fundamental steps has been addressed in the Science Paper or other documents provided for the Batemans Marine Park. The issue of protection is obliquely mentioned, and it is clearly implied that declaring a zone as a sanctuary provides protection, but the fishing closures proposed, particularly in estuaries and on ocean beaches, offer no protection from the threats identified to either habitats or the key species present. No evidence is even given that fishing in any of its many forms, as carried out in the Park, constitutes a real threat to either the species or the habitats of the area.

The Batemans Marine Park, as described in the documents provided by the Marine Parks Authority does not meet the Marine Parks Authority's own vision to, "have been derived through scientific assessments of all available information and data". The Science Paper and related documents are consistent only in being biased. The majority of statements that impact the impression of the benefits of marine protected areas and their relevance to the Batemans Marine Park are either a mis-interpretation of the source material, or an exaggeration, always in the direction of overstating benefits. This consistent bias cannot happen by chance. Where was Doc's father while this was going on? I can assure you the Science Paper provided by the Marine Parks Authority on the Batemans Marine Park does not constitute a work of genius: there are actually some statements in it which are correct! Such as the potential benefits of having well designed protected areas. It does, however, provide incontrovertible evidence that the documentation presented by the Marine Parks Authority is selective. It represents unjustified advocacy for the declaration of a marine park rather that scientific assessment of the needs for, and implications of, such a park. And yet it claims science is a key component of the whole process.

The real threats, as identified in the Science Paper, for example "pollution, siltation, (and) introduced species", are not addressed at all in the proposed actions. The management measures implemented are all nothing more than restraints on fishing. None of the key threats identified for estuaries are addressed in any way. Almost all of the other listed causes of "direct damage", "introduced marine pests, swing mooring chains, propellers, retrieval of anchors", are totally ignored, except for retrieval of anchors, which is specifically mentioned in the zoning plan as being permitted in all zones, including sanctuaries, except over seagrass beds in sanctuaries. Thus there is extremely little action against anything, even if it has been identified

as a threat, except fishing of any sort. The Batemans Marine Park is nothing more than an external agency imposed fisheries management measure, and an extremely poorly conceived and designed one, at that. Why the Marine Parks Authority has been allowed to introduce and then administer measures which are solely fisheries management when New South Wales has another body, DPI, with the legislated responsibility for fisheries management, is another matter.
Because of their implications for fishing what the proposed closures in the Batemans Marine Park will do, is allocate fish stocks away from those individuals who previously fished in the areas that are now closed. The actual data in the documentation provided or cited by the Marine Parks Authority clearly show that individuals who fish in adjacent areas are most unlikely to receive any advantage from "improved fish stocks". Individuals fishing on ocean beaches and in estuaries will certainly not receive any significant benefit. They will also have to accommodate additional fishing effort from those who pay the cost, substantial in many cases, and relocate their fishing effort to the adjacent areas. The obvious outcome is that one group of fishers will be seriously disadvantaged by having to move, at considerable cost and with grave effects on lifestyle if their current place of domicile is related to access fishing sites, and the remaining group will have to accommodate increased fishing effort at their current sites where there will be no detectable improvement in fish stocks. These problems will be particularly acute for individual recreational anglers who do not have boats or 4WD vehicles and who go on foot to their preferred fishing sites. Children, the elderly and the poor, whose voices are seldom listened to, are prominent in this category.

In the absence of specific stock management benefits for individual species the proposed closures are a resource allocation measure for no assessed positive conservation or stock management outcome. The world has many examples of disastrous fisheries management from resource allocation being packaged and marketed, incorrectly, as resource conservation. Other forms of natural resource management in Australia, for example water management, are now suffering from the same mistake of allocation being assumed to solve conservation problems. If there are specific fish stock conservation measures that need addressing, and for which area closures are the appropriate management tool, then have them identified. Only then can the realistic benefits of the proposals be assessed, the measures necessary to test their effectiveness be designed and appropriate adaptive management begun. The most effective measures to counter identified threats may well be area management, such as MPAs, but their design will need to take into account proper scientific assessment of their possible benefits and how to achieve them. Hopefully it will also acknowledge the problems with the use of MPAs, such as the true financial and social costs, potential economic and management inefficiencies, inter and intra agency duplication and the difficulties in accommodating the problems of the differing requirements of individual species and the complex environments and high degree of connectivity of marine ecosystems. I elaborated on several of these in my submission of October 15, 2006 to the Marine Parks Authority.

The documentation relating to the creation of the Batemans Marine Park is perhaps best described as very poorly disguised advocacy marketed to the unsuspecting public as science. This is a sham. So much so that not only does it totally discredit the Batemans Marine Park but it calls into question the credibility of the Marine Parks Authority and the justification of all existing and proposed marine parks in New South Wales.

Back to the subject of this talk: who has been hoodwinked? To begin with, anybody who has read the documentation on the Batemans Marine Park provided by the Marine Parks Authority and believed that it represented an unbiased assessment. To this should be added anybody, such as myself, who made a submission to the Marine Parks Authority on the subject of the Batemans Marine Park thinking that consideration would be given to such submissions. Assuming that Ministers Macdonald and Debus believed that the Batemans Marine Park had been established according to their own stated principles for marine parks in NSW, "scientific research programs that adhere to world's best practice standards are required to identify the best places for new marine parks, the best arrangements of zones within them and the most appropriate management practices to be used to run them" (Macdonald and Debus 2004), and why wouldn't they if their own agency told them that the science was sound?; then they were clearly hoodwinked. So was there anybody who believed what these two ministers subsequently said indicating that the declaration of the Park was based on science and would have assessed benefits? Has the Marine Parks Authority been hoodwinked by the authors of its own reports? The bias in the documents is so consistent it is hard to believe management was not complicit. Additionally, they were told of these problems in at least some of the submissions they received, yet they did nothing about them. Even those individuals who receive benefit from managing and promoting the park may have been hoodwinked. This would depend on whether or not they actually believe the Park was justified on the basis of the information that was available.

Many citizens of the Batemans region have been hoodwinked into believing that the proposal for this park was actually based on sound science and that the park will deliver considerable benefits to biodiversity conservation and recreational fishing. The email traffic on this subject identifies many who were seduced into believing that the short-term pain will lead to long-term gain. Unfortunately this is far from the truth. Not only is it extremely unlikely there will be any demonstrable benefit to recreational fisheries, certainly not on ocean beaches or in estuaries, but the case for having future beneficial area management will be seriously weakened by the experience of these closures failing to deliver. The community will not be pleased when it is asked to accept additional management measures that will undoubtedly be necessary to appropriately address the real threats. One is reminded of the story of the little boy who cried wolf. There are almost certainly marine areas, species and habitats in the Batemans region that require protection and many that would benefit from efficient area management; examples include protection of estuaries from known threats such as siltation and pollution, area management of abalone fisheries, the closure of all inshore areas to fish trawling, and reduction in threats from introduced pests, such as aquatic weeds. It is such a pity tax payers' money and public good-will for conservation have been so needlessly misdirected by advocacy for more parks posing as science in the asserted cause of conservation and sustainability. The goal of having effective marine parks in NSW based on sound science has been seriously set back. And to date, we fish biologists have sat back and watched it happen.

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