Marine protected areas in New South Wales, Australia: challenges for research

R. G. Creese and D. A. Breen

NSW Fisheries, Port Stephens Fisheries Centre

Private Bag 1, Nelson Bay NSW 2315, Australia

Email: bob.creese@fisheries.nsw.gov.au

ABSTRACT

The use of marine protected areas as a major tool in marine conservation is now accepted throughout much of the world. New South Wales is committed to a process of establishing a comprehensive system of marine protected areas for all marine waters under its jurisdiction. The current status of the NSW system is presented here and the role of science in the process of establishing and managing that system is explored. Scientific analysis has been able to greatly assist the selection of candidate sites for marine protected areas along the NSW coast, but the challenge for scientists now is to develop monitoring and evaluation procedures that will provide the basis for continuous improvement of the system. This is particularly important if the arrangement of marine protected areas is to function as an effective ecological network rather than merely as a collection of ecologically isolated elements.

Key words: Marine protected areas, New South Wales, monitoring, evaluation

Introduction

Marine protected areas are increasingly being used around the world as a major tool for conserving marine biodiversity, protecting marine habitats and ensuring the sustainability of harvest fisheries (Kelleher *et al.* 1995, Lubchenco *et al.* 2003). Their effectiveness varies according to their size, degree of protection and extent of compliance, but many published studies, almost all of which have used harvested fish species as their indicators of performance, have demonstrated substantial increases in population densities, biomass, average organism size and species diversity (Halpern 2003). Even small reserves, such as the Leigh Marine Reserve in New Zealand (established in 1975), have shown dramatic increases in numbers of heavily fished species such as snapper and rock lobsters (Babcock 2003). This particular reserve, like most of the others that have demonstrated dramatic improvements in the numbers or biomass of some species, has been labeled a "no take" marine protected area.

The notion of setting aside areas of the sea as protected areas that have "no take" components is a recent one. New Zealand, which played a leading role in the development of this concept, created several "no take" marine reserves at the end of last century (Creese and Cole 1995). The New Zealand government continues to declare new marine reserves, with a long-term goal of having 10% of the coast under this form of protection. However, the process for investigating new areas for reservation in New Zealand is based on local nominations by stakeholder groups. This process has meant that New Zealand still does not have a structured arrangement of its reserves, although such an arrangement has often been advocated (e.g., Ballantine 1997).

The establishment of marine protected areas is one tool available to governments to manage their marine resources in a judicious and sustainable way. The NSW Government, along with other Australian states, has moved away from haphazardly placed, single marine protected areas, towards comprehensive systems that aim to conserve representative examples of the marine ecosystems throughout their jurisdictions. Much has been written about the need for fully protected marine reserves and how to design them (e.g., Roberts *et al.* 2003), but there are few examples of where integrated systems of marine protected areas are being actively implemented.

We distinguish here between a 'system' of marine protected areas and a 'network'. The former is an arrangement of protected areas structured in such a way as to represent, as best as possible, the range of marine biodiversity and habitats present within some much larger area. A network, on the other hand, uses ecological functioning of marine ecosystems as its primary objective. A system is primarily designed to protect the full range of elements in a large area whereas a network seeks to also protect potentially important ecological linkages among those elements (e.g. larval dispersal) (e.g., Roberts *et al.* 2001).

A system of representative reserves is progressively being established along the entire coast of NSW, with the major elements expected to be in place within the next five years. The primary goal of the system is the conservation of marine biodiversity rather than the protection or enhancement of fisheries resources. The development of this system has relied heavily on an analysis of existing information (see Breen *et al.* in press b) to select the best available sites and to provide marine protected area

Pp 120 - 128 in *Conserving marine environments. Out of sight out of mind*, edited by Pat Hutchings and Daniel Lunney 2003. Royal Zoological Society of New South Wales, Mosman, NSW.

Downloaded from http://meridian.allenpress.com/zsnsw-other-books/book/chapter-pdf/2643465/fs_2003_014.pdf by guest on 01 February 2023

managers with a range of options. The selection process is now complete, and large marine parks are being created with substantial areas of fully protected sanctuary zones (or "no take" areas) within them.

This paper summaries the current status of the emerging system of marine protected areas in NSW, describes the role of science in the initial identification and selection phases and identifies the additional scientific input that is needed in subsequent phases. We argue that the effectiveness of marine protected areas in conserving marine biodiversity can only be properly assessed by rigorous scientific evaluation.

Marine protected areas in NSW

New South Wales has a relatively simple coastline stretching over 1,000 kilometres along the southeast coast of Australia from 28°15'S to 37°30'S. In the north, subtropical waters flow south from the Coral Sea as the East Australian Current. In the south, cold temperate waters flow north from Bass Strait. Warm temperate conditions prevail along the central part of the coast. The coast is incised by several drowned river valleys, barrier estuaries and over 100 coastal lakes and lagoons ranging in size from a few hectares to over 100 km^2 (Figure 1).

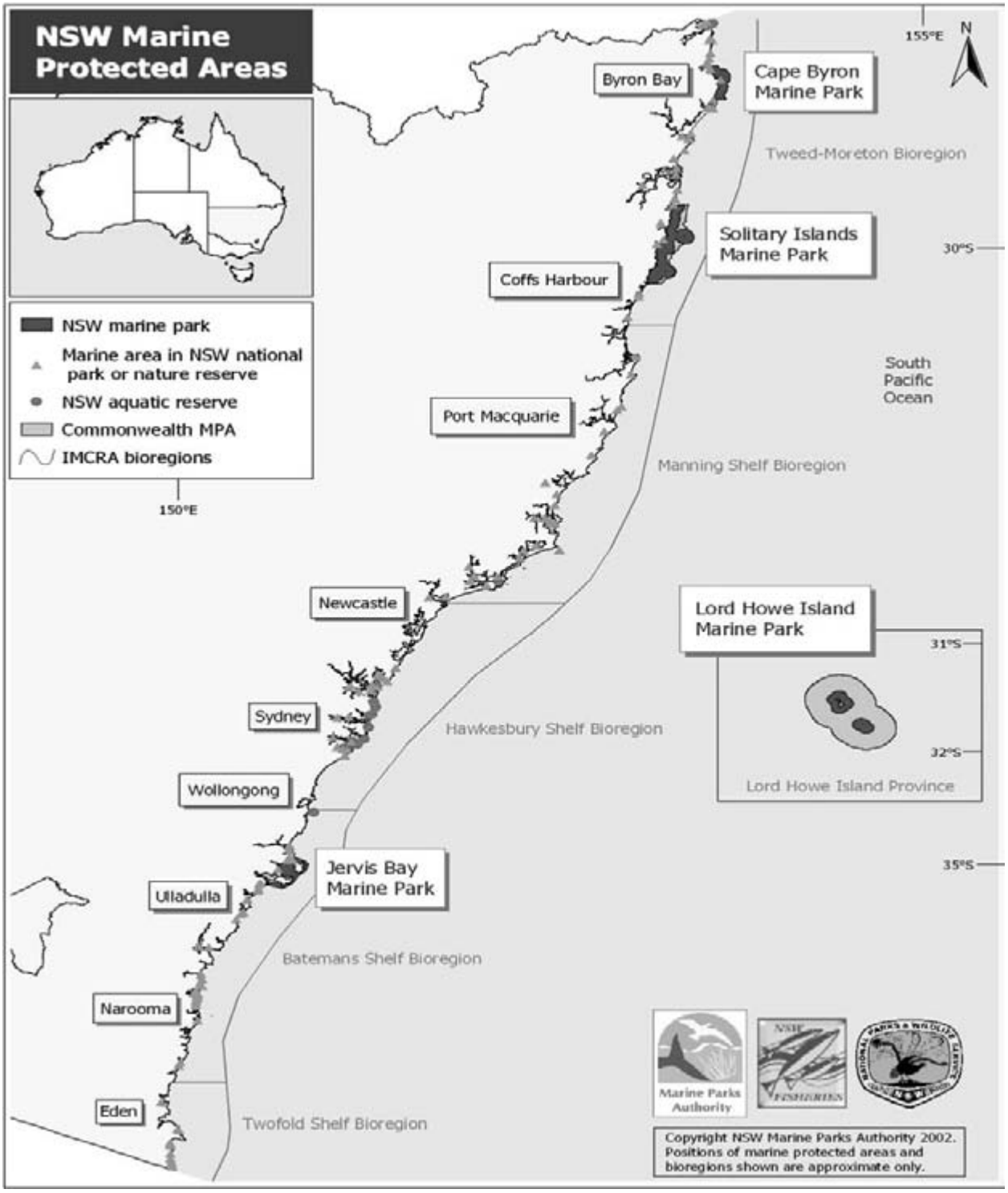

Figure 1. The marine bioregions of NSW and the locations of existing marine protected areas.

Downloaded from http://meridian.allenpress.com/zsnsw-other-books/book/chapter-pdf/2643465/fs_2003_014.pdf by guest on 01 February 2023

During the 1990s, an evaluation of existing physical, sedimentological, oceanographic and some biological data on Australia's coastal marine environment led to the recognition of 65 marine bioregions around the country (IMCRA 1998). These bioregions are the framework for developing a national representative system of marine protected areas using national guidelines developed at the time (ANZECC TFMPA 1998). There are five marine bioregions along the mainland coast of NSW and one marine province centered on Lord Howe Island 500 km offshore (IMCRA 1998). The bioregions extend out to the continental shelf break, at a depth of approximately 200 m. Only the immediate nearshore strip of the coastal bioregions is contained in state territorial waters, which extend out to 3 nautical miles. Only these areas are considered in the following discussion The waters beyond 3 nautical miles, and out to the limit of the 200 nm limit of the Exclusive Economic Zone, are administered by the Commonwealth Government. The Tweed-Moreton bioregion in the north of NSW extends into southern Queensland waters, and the Twofold Bioregion in the south is mostly in Victoria with a small extension into NSW (Figure 1).

Using these 6 biogeographic units, the NSW government has made a commitment to establish a system of marine protected areas with comprehensive and adequate representation of the full range of marine biodiversity at ecosystem, habitat and species level (MPA 2001). The marine protected areas system has three components: large, multiple use Marine Parks (managed by the NSW Marine Parks Authority), smaller Aquatic Reserves (managed by NSW Fisheries) and marine extensions of terrestrial parks and reserves (managed by the NSW National Parks and Wildlife Service). The ultimate goal of the NSW system is to have at least one marine park in each bioregion, supplemented by aquatic reserves and other types of marine protected areas to ensure adequate protection for the range of marine biodiversity. Other goals and principles, and the procedures used to establish and manage the system, are contained in a NSW Government overview document (MPA 2001).

There are currently 4 Marine Parks and 14 Aquatic Reserves in NSW (Table 1) as well as numerous terrestrial reserves that have marine components (listed in MPA 2001). Marine parks and aquatic reserves can be zoned to provide fully protected "sanctuary" areas, as well as

Table 1. Marine protected areas in NSW administered under either the NSW Marine Parks Act 1997 (Marine Parks) or the NSW Fisheries Management Act 1994 (Aquatic Reserves) arranged from north to south. Information is correct as of 1 January 2003.

Marine protected area	Bioregion	Date of declaration	Approx. total area (ha)	Approx. area of sanctuary (ha)
1. Marine Parks				
Cape Byron	Tweed-Moreton	2002	22,740	To be finalised*
Solitary Island	Tweed-Moreton	1998	71,100	8,650
Lord Howe Is.	Lord Howe	1999	48,000	To be finalised*
Jervis Bay	Batemans	1998	21,450	4,300
2. Aquatic Reserves				
Cook Island	Tweed-Moreton	1998	74	30**
Julian Rocks ***	Tweed-Moreton	1982	76	
Fly Point – Halifax Park	Manning	1983	67	60
Barrenjoey	Hawkesbury	2002	29	
Long Reef	Hawkesbury	1980	76	
Narrabeen	Hawkesbury	2002	6	
Cabbage Tree Bay	Hawkesbury	2002	20	20
North (Sydney) Harbour	Hawkesbury	1982	260	
Bronte - Coogee	Hawkesbury	2002	43	
Cape Banks (La Perouse)	Hawkesbury	2002	22	
Boat Harbour	Hawkesbury	2002	72	
Towra Point	Hawkesbury	1990	1,401	563
Shiprock	Hawkesbury	1982	2	2
Bushrangers Bay	Batemans	1982	4	4

* Zoning options are currently being considered for these marine parks for finalisation later in 2003. The sanctuary areas for the other two marine parks were gazetted in 2002.

** This area is not strictly a sanctuary, but a "no-take" fishing closure.

*** The Julian Rocks Aquatic Reserve is wholly contained within the new Cape Byron Marine Park and will cease to exist as an aquatic reserve once the zoning plan for the Marine Park is finalised.

Downloaded from http://meridian.allenpress.com/zsnsw-other-books/book/chapter-pdf/2643465/fs_2003_014.pdf by guest on 01 February 2023

less restricted areas designed to allow for a variety of sustainable uses. Sanctuaries are equivalent to terrestrial National Parks and to the "no take" marine reserves referred to in recent international literature (Ballantine 1997, Lubchenco *et al.* 2003). Prior to 2002, there were only small marine areas of coastal NSW protected in sanctuary zones, within the Solitary Islands Marine Park and three aquatic reserves. However, under new zoning plans for the four existing marine parks, much larger areas have become, or soon will become, sanctuaries (Table 1). Extensive consultation with stakeholders in the marine parks is used to develop draft, and then final, zoning plans, which are reviewed every five years (MPA 2001).

Zoning plans divide marine parks into four categories. These categories are detailed in the NSW Marine Parks regulation 1999 and are explained in MPA (2001) as follows:

- "**Sanctuary zones** allow for total protection of marine animals and plants and their habitats. Activities that involve harming any animal, plant or habitat are prohibited.
- **Habitat protection zones** give protection to habitat, but allow limited taking of specified fish and plants. Only activities that do not have a significant impact on fish populations and have negligible impact on other animals, plants and habitat are permitted.
- **General use zones** allow multiple use, as long as these are ecologically sustainable. Activities are subject to generic regulations that apply across the whole park, including permits.
- **Special purpose zones** are used when special management systems are required, including protection of Aboriginal and other cultural features, marine facilities, or for specific park management reasons."

Sanctuary zones provide the greatest protection by prohibiting all forms of extraction, but habitat protection zones also have significant conservation value by, for example, prohibiting trawling and other fishing techniques that can degrade benthic habitats. Following public submissions on draft zoning plans, changes may result before final zoning plans are accepted and gazetted. At the same time, operational plans are developed that detail how the Marine Park Authority will manage and operate the park over the five year period.

Research and monitoring play an important role in developing and evaluating the NSW system of marine protected areas. The Marine Parks Authority (MPA 2001) notes that research and monitoring will be used to:

- "establish a comprehensive, adequate and representative system of marine protected areas that includes a full range of marine biodiversity at ecosystem, habitat and species level
- provide baseline estimates of natural variation
- monitor impacts on these natural conditions
- trigger and prioritise management responses
- determine strategies for managing specific areas, ecosystems, species and threats
- determine strategies for integrated management of wider issues
- monitor the success of management in conserving biodiversity
- direct future management, research and monitoring".

A Marine Park Research Committee (MPRC) has been established to advise the Marine Park Authority on matters pertaining to research and monitoring. A strategic framework for marine park monitoring and evaluation (MPA in press) identifies two overarching priorities:

- **Identification & selection**: The scientific procedures by which new marine parks are selected and their boundaries and zoning arrangements determined.
- **Evaluation**: The ways in which established marine parks (especially their boundaries, zoning and other management arrangements) are scientifically evaluated by long-term monitoring.

The ways in which science has been used to date to inform the development of a representative system of marine protected areas in NSW and the challenges for future scientific activities are examined below under these two headings. A final section considers the need for additional research and monitoring targeted at particular issues in individual marine parks and advocates the establishment of a robust and transparent system for incorporating the results from research and monitoring into policy development and management actions.

Identification and selection

At present, marine protected areas are unevenly distributed among the bioregions (Table 1), due to the historical circumstances under which they were declared. A more systematic approach has been in place since 2000 to identify candidate areas in the five coastal bioregions to ensure adequate representation of key components of the marine environment across the entire system of marine protected areas in NSW. This approach has taken the form of "bioregional assessments", which have been completed for all coastal bioregions (i.e., excluding Lord Howe Island). Only one of these assessments is publicly available at time of writing (Avery 2001), but others will be released in due course.

There are no generally accepted criteria for determining the optimal size of marine protected areas or the size and arrangement of zones within multiple use marine parks or aquatic reserves. However, considerable attention has been devoted to this issue and similar ecological criteria have emerged in recent reviews (see, for example, Breen *et al.* in press a, Roberts *et al.* 2003). Two criteria generally recognised as of prime importance when designing a network of marine reserves are 'biogeographic' representation and 'habitat' representation (Roberts *et al.* 2003). Both these criteria were incorporated into the early planning stages of the NSW Representative System of Marine Protected Areas. Population modeling (e.g. Gerber *et al.* 2003) can help provide preliminary insights into reserve design, but direct tests using empirical data collected from existing marine protected areas ultimately will be necessary. Ecological and life history features vary considerably among marine

Downloaded from http://meridian.allenpress.com/zsnsw-other-books/book/chapter-pdf/2643465/fs_2003_014.pdf by guest on 01 February 2023

species on several spatial and temporal scales. It is unlikely, therefore, that a marine protected area network can be established, either at the level of a bioregion or of the whole NSW coast, that is simultaneously effective for all marine biodiversity. Nevertheless, in the long-term, research on the NSW coast needs to more directly address issues of the size, shape and spacing of marine protected areas.

NSW marine parks do not target particular species for conservation, although certain zones within a multiple use marine park may do so. Where sufficient data exist, attempts can be made to estimate the optimum size and configuration of protective zones for particular species or taxonomic groups. This approach is reliant on a high level of ecological information about those taxa, and can only be applied to well-studied taxa such as corals or rocky intertidal gastropods. It results, therefore, in an inevitable bias towards the few, well-studied taxa in a particular habitat or ecosystem. The ecology of most marine species along the NSW coast is largely unknown, so this approach will rarely have practical value for a system of marine protected areas that attempts to conserve all biodiversity.

Another approach to determine the optimal size of marine protected areas (either whole marine parks or sanctuary zones within them) is by modeling techniques such as examining the percentage of species richness represented with increasing size of the protected area (Crosby *et al.* 2000, Salm *et al.* 2000, Neigel 2003). The application of this approach for the NSW coast is limited by the fact that quantitative measures, such as species richness or species diversity, are inadequately documented for most marine habitats. Further, this type of modeling consistently predicts that, the larger area, the more species that will be represented (Salm *et al.* 2000). This result argues for making marine protected areas as large as possible. There may be considerable practical difficulties in implementing very large reserves, however, due to higher costs for compensation of displaced stakeholders, management and compliance. The trade-offs between size and management cost and between size and replication (i.e. several small areas rather than a few large areas) need to be carefully evaluated. Some theoretical predictions may be possible at the selection stage for marine protected areas, but these will always need to be tested by rigorous sampling once the final arrangement is in place.

The necessary data on biodiversity or the ecology of key species are not currently available for most NSW coastal habitats. Consequently, the options for the location of marine parks or the zoning boundaries within them must rely on techniques that use larger scale, surrogate measures as the basis for identification and selection. In each bioregion in NSW, several habitat surrogates (shown in Figure 2) were mapped as layers within a Geographical Information System (ArcView 3.2). These GIS layers, along with any available data sets on the spatial distributions of particular taxa, were then subjected to analysis using various decision support tools, particularly a software program called C-Plan developed by the NSW National Parks and Wildlife Service (for further details, see Breen *et al.* in press a, b). The use of these sorts of analytical techniques have long been used for terrestrial environments (Pressey *et al.* 1994) and are now being recommended for planning systems of marine reserves (Leslie *et al.* 2003).

C-Plan and other programs like MARXAN (Day *et al.* 2002) can be used to systematically explore options for marine protected area systems that meet goals for representing a variety of ecosystems, habitats, species and other features while minimising costs in area and other constraints. The value of a particular site to a system of marine protected areas is related to the features (species or habitats) it includes and how that site may complement the range of features already represented in MPAs. A site with many species and habitats may not add anything to an existing network if all goals already have been met for those features. However, a site with one feature not found elsewhere may be virtually irreplaceable and it will therefore be an essential requirement if a system of reserves is to meet a particular conservation goal.

Including new locations in a reserve continually alters the potential value of remaining areas in meeting overall goals. C-Plan statistically estimates these values as 'irreplaceability' "the likelihood that an area will be required to achieve a set of targets" or "the extent to which the options for achieving the targets are reduced if the area is unavailable for conservation" (Pressey *et al.* 1994).

The system being put in place in NSW is not yet a network, but analysis with C-Plan and other decision support tools has proved very useful in identifying options for the comprehensive representation of marine biodiversity within NSW marine parks. Mapped data from GIS layers also can be presented as the amounts of a particular habitat type occurring in different parts of a bioregion. This enables rapid visual assessmsnt of which locations within a bioregion contain the largest amounts of a particular habitat type (see example in Figure 3).

While the use of coarse habitat surrogates is the best approach currently available, other ways of assessing the biodiversity values of marine habitats should be developed to take account of issues such as connectivity, the presence of biodiversity hotspots or areas that may be sources for reproductive propagules or sinks for recruitment. Preliminary trials of new techniques for measuring marine biodiversity in coastal NSW are under way (A.J.Underwood, University of Sydney, pers. comm. 2002) and further refinement of these techniques and the development of other approaches is encouraged. When it comes to evaluating the effectiveness of zoning plans within a marine park, relying on coarse surrogates for biodiversity will not be sufficient.

Evaluation

Once the site for a marine park has been identified at a bioregional level, more detailed field-based studies are required to assess the validity of broad-scale predictions. This will usually require the collection of more detailed, site-specific information that can be used to assess local patterns of biodiversity, reserve design, potential threats and other issues relating to management. This step is an essential component of the research program for any established marine park and would be expected to provide data to assist the development of a draft zoning plan.

Downloaded from http://meridian.allenpress.com/zsnsw-other-books/book/chapter-pdf/2643465/fs_2003_014.pdf by guest on 01 February 2023

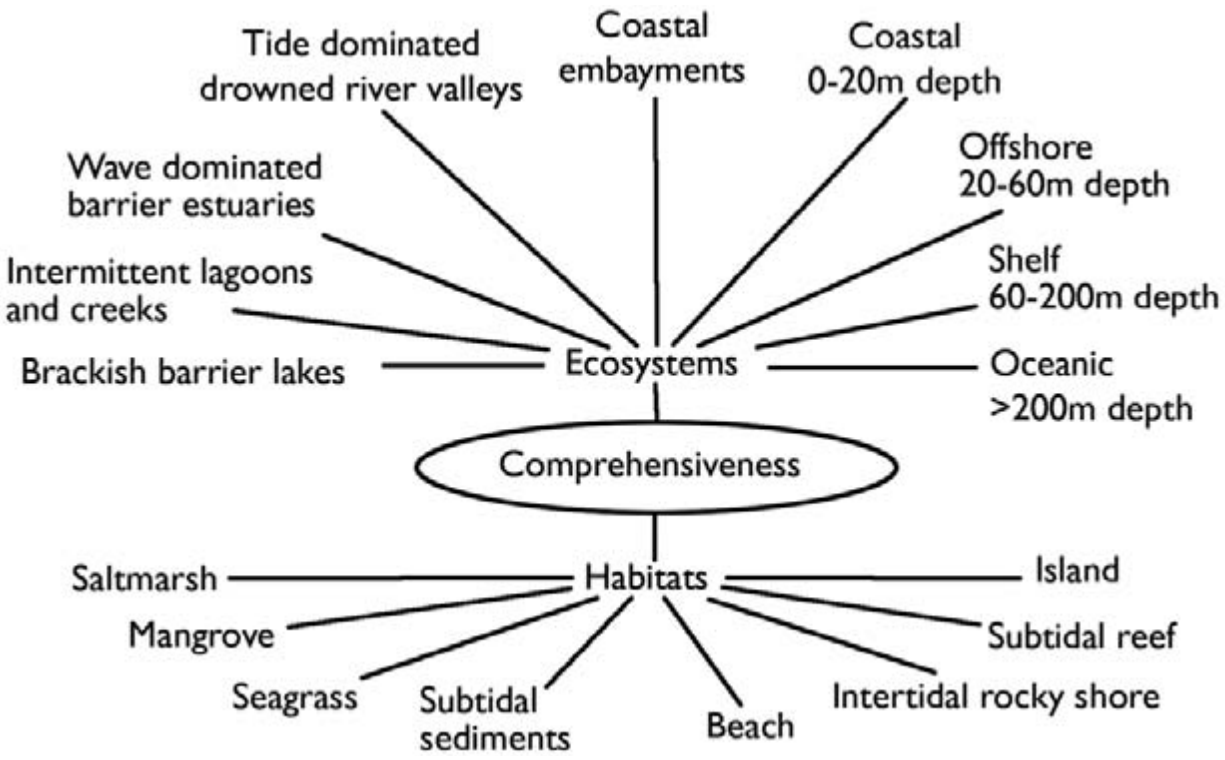

Figure 2. Habitat and ecosystem surrogates used for representing biodiversity within marine protected areas in NSW (from Breen *et al.* in press a).

Habitat mapping is an important component of the initial surveys. The coastal marine environment is not homogeneous, and habitat units can usually be readily recognised within the boundaries of a marine park. The habitats used in the bioregional assessments for the NSW coast are broad, and their positions were only approximately identified by means of remote techniques such as aerial photographs and depth sounders (Breen *et al.* in press). This scale is often too coarse for monitoring purposes once a marine park is established.

Initial surveys also establish the "before" condition against which any changes that occur through time can be assessed. This requires the collection of baseline information over a larger set of sites than just those that will be subsequently protected in some way. Because the establishment of different zones within the boundaries of a marine park represents a manipulative experiment, it is vital to design monitoring programs that allow a quantitative and rigorous evaluation of any changes (expected to be improvements) that occur following protection.

In general, these evaluation projects should follow a BACI (before, after, control, impact) experimental design with adequate replication and multiple control sites (i.e. areas outside the marine park), and should involve regular sampling on a predetermined temporal basis (Kingsford and Battershill 1998). If sampling can be done at several times before a zone plan goes into operation, the greater the ability to identify changes that might be attributable to the changed management arrangements. One-off sampling exercises at a limited number of sites are unlikely to provide data that can be used to evaluate reliably the effectiveness of marine parks or other protected areas.

It is generally accepted that some form of stratified sampling is desirable to achieve better precision when assessing changes in the abundances of marine organisms over time (e.g. Kingsford and Battershill 1998). Thus, an understanding of how habitat units are distributed within a marine protected area is a valuable asset when initiating long-term monitoring on both hard and soft substrata (Kingsford and Battershill 1998, Barrett *et al.* 2002). Detailed maps of the main habitats within a marine park would greatly aid the design of ongoing monitoring programs.

A commitment to a core monitoring program, stratified by habitat, would go a long way to assessing whether zoning plans and other management arrangements were meeting their primary objectives. Ultimately, such monitoring activities should ensure that marine parks are being managed sustainably. Core monitoring activities are notoriously difficult to adequately resource because of the long time frames needed and the spatial scales to be considered (Underwood and Kennelly 1990, Thompson and Mapstone 2002), but essential evaluation is impossible in the absence of quantitative data. Rigorous experimental designs are needed for these monitoring programs to allow proper statistical analysis of the resulting data (Underwood 1997).

If marine protected areas are to deliver all that is expected of them, they will have to form effective ecological networks rather than merely unlinked spatial units. For example, if one goal for sanctuary zones is to replenish adjacent unprotected areas within a marine park, then the flow of fish recruits from that sanctuary needs to be understood (Leis in press). Studies on larval dispersal, ontogenetic shifts in habitat and adult migrations will be needed to provide information on how different spatial units are functionally linked. Wherever possible, all stages in the life history of key organisms should be monitored.

Downloaded from http://meridian.allenpress.com/zsnsw-other-books/book/chapter-pdf/2643465/fs_2003_014.pdf by guest on 01 February 2023

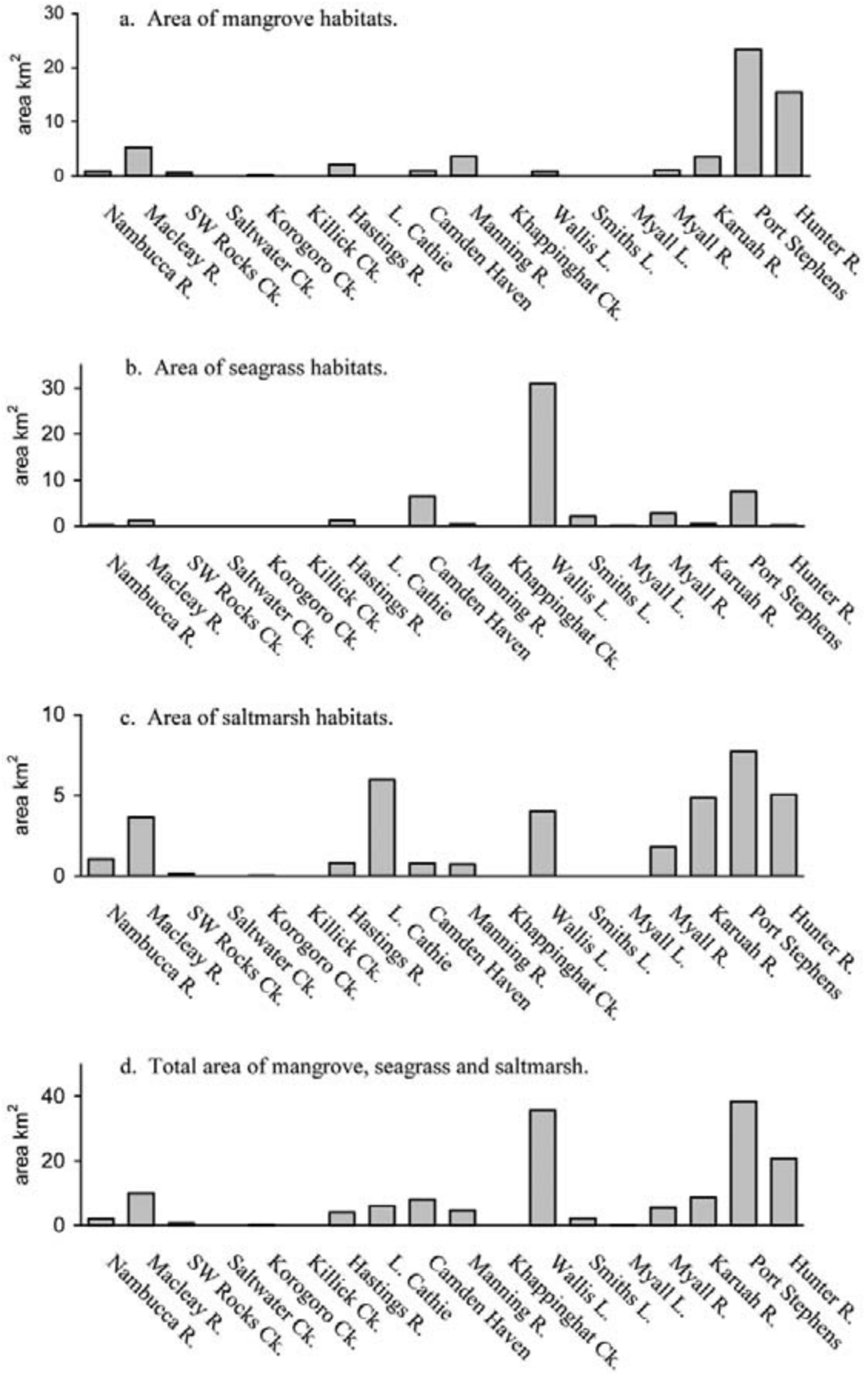

Figure 3. Areas of three habitat types (a) - (c) and their totals (d) within estuaries of the Manning Shelf Bioregion (from Breen *et al.* in press b).

Downloaded from http://meridian.allenpress.com/zsnsw-other-books/book/chapter-pdf/2643465/fs_2003_014.pdf by guest on 01 February 2023

General research

The Marine Park Research Committee, in consultation with marine parks staff, is charged with developing comprehensive research plans for each marine park in NSW. Because marine protected areas are deliberately selected to protect a representative sample of marine biodiversity, they logically could become a major focus for marine biodiversity research in NSW. Consequently, university and other researchers are encouraged to undertake research activities in marine parks (and other marine protected areas). For example, some of the best information about underwater ecological processes on temperate coasts comes from studies done in marine reserves by university-based researchers (e.g. Babcock 2003). In NSW, some of the best scientific work on corals has been done in the Solitary Islands (e.g. Harriot 1994) and Lord Howe Island Marine Parks.

Five categories have been developed to identify the range of targeted research that is needed in marine parks and other marine protected areas in NSW (MPA in press):

1. Biodiversity and ecological processes
2. Indigenous and non-indigenous culture and heritage
3. Ecologically sustainable use
4. Specific impacts
5. Socio-economic impacts

Research projects within these categories for individual marine parks will cover a wide range of topics from basic marine biology to cultural issues and specific management-oriented research. For example, impacts of activities such as anchoring, diving and recreational fishing may require specific monitoring. Habitat protection zones in parks such as Cape Byron Marine Park, where trawling has been practised for many years, provide an ideal opportunity to test recovery of benthic habitats following the cessation of this fishing activity (see also Burridge *et al.* 2003). The presence of threatened or 'icon' species in a particular marine protected area should merit special investigation. Aggregations of endangered grey nurse sharks *Carcharias taurus* around the offshore islands in the Solitary Islands Marine Park and at Julian Rocks in the Cape Byron Marine Park, for example, provide good opportunities for detailed investigations of localised movement patterns.

For a system of marine protected areas to be effective, community support is essential. This can only be gained if people are properly informed and educated about the goals and values of marine protected areas (Lubchenco *et al.* 2003). The results of scientific research can play an important part in this education. Local communities and stakeholders should be kept informed about the research being done in their local marine park. There are often opportunities for local community groups to assist with the collection of valuable information. Along the NSW coast, for example, local dive clubs have actively participated over several years in counting numbers of *Carcharias taurus* on specified weekends. These data have allowed much better estimates of population numbers than were previously available (Otway *et al.* 2003).

Researchers working in marine parks have an obligation to provide accurate information on the marine resources in them. Scientific outputs arising from research and monitoring in marine parks and other marine protected areas should provide direct input into management and policy development. Management plans for marine parks, therefore, should have assessable goals that allow for evaluation through rigorous research at appropriate temporal and spatial scales. The partnership between research and management should be regarded as an ongoing and iterative process to improve management and the understanding of the marine environments along the NSW coast (Leis in press, Breen *et al.* in press a).

Conclusion

NSW is well advanced in the process of establishing a representative system of marine protected areas. The identification and selection phase is nearly complete. Analyses of existing data sets during this initial phase have highlighted the rudimentary state of our knowledge about the marine biota along the NSW coast. Appropriate levels of research and monitoring are now required to provide the range of information needed to evaluate how well the new system performs in meeting its objectives.

Acknowledgements

This overview benefited from discussions over several years with many colleagues including Nick Otway, Steve Kennelly, Bob Pressey, Simon Banks, Kelly Waples, Dave Priddel, Rodney James, Tim Lynch, Hamish Malcolm, Gee Chapman, Tony Underwood, Trevor Willis, Russ Babcock and Bill Ballantine. Helpful management perspectives came from Andrew Read, Libby Sterling, Graham Byron and Paul O'Connor. All are thanked for their valuable contributions.

References

ANZECC TFMPA. 1998. Australian and New Zealand Environment and Conservation Council, Task Force on Marine Protected Areas. Guidelines for establishing the national system of marine protected areas. Environment Australia. Canberra, Australia.

Avery, R. P. 2001. Byron Bay area assessment, Tweed-Moreton Bioregion, northern NSW: A review of the current marine biodiversity data sets and an introduction to systematic marine protected area planning in NSW. A NSW National Parks Wildlife Service Report to the NSW Marine Parks Authority.

Babcock, R.C. 2003. The New Zealand Marine Reserve Experience: the science behind the politics. Pp 108-119 in *Conservation of Marine Environments*, edited by P.A. Hutchings and D. Lunney, Royal Zoological Society of NSW, Mosman, NSW.

Ballantine, W.J. 1997. Design principles for systems of 'no-take' marine reserves. P4 in *The design and monitoring of marine reserves*. Vol. 9, No. 1. Edited by T.J.Pitcher. Fisheries Centre, University of British Columbia, Vancouver, Canada.

Downloaded from http://meridian.allenpress.com/rzsnsw-other-books/book/chapter-pdf/2643465/fs_2003_014.pdf by guest on 01 February 2023

Barrett, N. and Buxton, C. (eds) 2002. *Examining underwater visual census techniques for the assessment of population structure and biodiversity in temperate coastal marine protected areas.* Tasmanian Aquaculture & Fisheries Institute, Technical Report Series No. 11. 114pp.

Breen, D.A., Avery, R.P. and Otway N. (in press a). *Broadscale biodiversity assessment of the Manning Shelf Bioregion*. Marine Parks Authority, Sydney, Australia.

Breen, D.A., Avery, R.P. and Otway N. (in press b). Broadscale biodiversity assessments for marine protected areas in New South Wales Australia. Proceedings of the World Congress on Marine Protected Areas. Cairns, Queensland, Australia.

Burridge, C.Y., Pitcher, C.R., Wassenberg, T.J., Poiner, I.R. and Hill, B. 2003. Measurement of the rate of depletion of benthic fauna by prawn (shrimp) otter trawls: an experiment in the Great Barrier Reef, Australia. *Fisheries Research* **60:** 237-253.

Creese, R.G. and Cole, R.G. 1995. Marine conservation in New Zealand. *Pacific Conservation Biology* **2:** 55-63.

Crosby, M.P., Greenen, K.S. and Bohne, R. 2000. Alternative access management strategies for marine and coastal protected areas: a reference for their development and assessment. Man and the Biosphere Program. Washington, D.C. USA.

Day, J., Fernandes, L., Lewis, A., De' Ath, G., Slegers, S., Barnett, B., Kerrigan, B., Breen, D., Innes, J., Oliver, J., Ward, T. and Lowe, D. 2002. The representative areas program – protecting the biodiversity of the Great Barrier Reef World Heritage Area. *Proceedings of the 9th International Coral Reef Symposium.* Bali, Indonesia, 2000 Vol. 1: 687-696.

Gerber, L., Botsford, L.W., Hastings, A, Possingham, H.P., Gaines, S.D., Palumbi, S.R. and Andelman, S. 2003. Population models for marine reserve design: A retrospective and prospective synthesis. *Ecological Applications* **13:** S47-S64.

Halpern, B.S. 2003. The impact of marine reserves: do reserves work and does size matter *Ecological Applications* **13:** S117-S137.

Harriot, V. J., Smith, D. A., and Harrison, P. L. 1994. Patterns of coral community structure of subtropical reefs in the Solitary Islands Marine Reserve, Eastern Australia. *Marine Ecology Progress Series* **109:** 67-76.

IMCRA. 1998. Interim marine and coastal bioregionalisation for Australia, Version 3.3. Environment Australia. Canberra, Australia.

Kelleher, G.C., Bleakley, C. and Wells, S. 1995. A global representative system of marine protected areas. The World Bank, Washington D.C., USA.

Kingsford, M.J. and Battershill, C.N. (eds) 1998. *Studying Temperate Marine Environments: a handbook for ecologists*. Canterbury University Press, Christchurch. 334pp.

Leis, J.M. in press. What does larval fish biology tell us about the design and efficacy of marine protected areas? Proceedings of the World Congress on Marine Protected Areas. Cairns, Queensland, Australia.

Leslie, H., Ruckelshaus, M., Ball,I.R., Andelman, S. and Possingham, H.P. 2003. Using siting algorithms in the design of marine reserve networks. *Ecological Applications* **13:** S185-S198.

Lubchenco, J., Palumbi, S.R., Gaines, S.D. and Andelman, S. 2003. Plugging a hole in the ocean: the emerging science of marine reserves. *Ecological Applications* **13:** S3-S7.

MPA 2001. Developing a representative system of marine protected areas in NSW – an overview. NSW Marine Parks Authority. Sydney, Australia. 36pp.

MPA in press. Strategic framework for the evaluation and monitoring of marine parks in NSW. NSW Marine Parks Authority. Sydney, Australia.

Neigel, J.E. 2003. Species-area relationships and marine conservation. *Ecological Applications* **13:** S138-S145.

Otway, N.M., Burke, A.L., Morrison, N.S. and Parker, P.C. 2003. Monitoring and identification of NSW critical habitat sites for the conservation of Grey Nurse Sharks**.** *NSW Fisheries Final Report Series No.47.* 62pp.

Pressey, R.L., Johnson, I.R., and Wilson, P.D. 1994. Shades of irreplaceability: towards a measure of contribution of sites to a reservation goal. *Biological Conservation* **80:** 2017-2019.

Roberts, C.M. and Hawkins, J.P. 2000. *Fully-protected marine reserves: a guide.* World Wide Fund for Nature, Washington.

Roberts, C.M., Halpern, B.S, Palumbi, S. and Warner, R.R. 2001. Designing marine reserve networks. *Biological Conservation in Practice* **2:** 10-17.

Roberts, C.M., Andelman, S., Branch, G.M., Bustamante, R.H., Castilla, J.C., Dugan, J.E., Halpern, B.S., Lafferty, K.D., Leslie, H., Lubchenco, J., McArdle, D., Possingham, H.P., Ruckelshaus, M. and Warner, R.R. 2003. Ecological criteria for evaluating candidate sites for marine reserves. *Ecological Applications* **13:** S199-S215.

Salm, R.V. Clark, J.R. and Siirila, E. 2000. Marine and coastal protected areas: a guide for planners and managers. Third edition. Gland, Switzerland. International Union for Conservation of Nature and Natural Resources.

Thompson A.A. and Mapstone B.D. 2002. Intra vs inter-annual variation in counts of reef fishes and interpretations of long term monitoring studies. *Marine Ecology Progress Series* **232:** 247-257.

Underwood, A.J.1997. *Experiments in ecology: their logical design and interpretation using analysis of variance.* Cambridge University Press, Cambridge. 504pp.

Underwood, A.J. and Kennelly, S.J. 1990. Pilot studies for designs of surveys of human disturbance of intertidal habitats in NSW. *Australian Journal of Marine and Freshwater Research* **41:** 165-173.

Downloaded from http://meridian.allenpress.com/rzsnsw-other-books/book/chapter-pdf/2643465/fs_2003_014.pdf by guest on 01 February 2023