Marine Protected Areas
in
Ecosystem-based Management of Fisheries

Trevor Ward and Eddie Hegerl

A report for the Department of the Environment and Heritage

August 2003

Natural Heritage Trust

Helping Communities Helping Australia

A Commonwealth Government Initiative

ISBN 0 642 54948 6

Authors
Trevor Ward - Marine Ecosystems Consultant, Perth, Western Australia
Eddie Hegerl - Marine Ecosystem Policy Advisors P/L, Brisbane, Queensland

Cover photography credits
Heron Island and Reef - L. Zell – Great Barrier Reef Marine Park Authority
Game fishing charter vessel and mother ship - Great Barrier Reef Marine Park Authority

Preface

This document has been prepared for marine conservation managers, fishery managers and government officials concerned with the development and implementation of marine protected areas. The intention is to provide some of the key concepts and supporting technical evidence for the dual and potentially complementary role of marine protected areas in both fisheries and conservation. In addition, we explore the use of protected areas as an important component of ecosystem-based management of fisheries.

The preparation of this document was made possible with funds from Australia's Natural Heritage Trust and the Department of the Environment and Heritage.

CONTENTS

Summary

Marine Protected Areas (MPAs) provide various levels of protection for marine ecosystems ranging from habitat protection to comprehensive protection of all biodiversity from the effects of human disturbance and use. All forms of MPAs make a contribution to the protection and management of biodiversity. The highest level of protection generally is provided in 'no-take' MPAs, where the intention is to fully protect species and their habitats from the removal of flora, fauna or the substrate.

MPAs have long been used in fisheries management to achieve a variety of objectives, but they have mainly been established to maintain fish stocks and their associated important habitats. However, MPAs created for fisheries purposes may also provide increased stability in fisheries, act as an offset for the unavoidable effects in fishing grounds, and help to maintain well-being in local communities. World-wide, many different types of MPAs also are used to achieve specific marine conservation objectives. While MPAs declared for fisheries purposes (such as areas closed to specific gear types, habitat reserves) also contribute to biodiversity conservation, this often is not well recognised or documented.

The MPAs created for fisheries purposes in Australia range from large closures to eliminate specific gear types (trawling) to smaller areas designed for specific habitat protection and protection of fishery nursery grounds. These MPAs contribute to the local, and possibly regional, conservation of biodiversity, although this has been only poorly documented. The objectives and management of these fishery closures vary from regulatory closures designed to allocate resources across individual sections of the fishing industry, to voluntary and non-regulatory community-based closures designed to rebuild fish stocks across a region.

MPAs have consistently been identified for their important potential role in supporting fisheries to become both ecologically and economically sustainable. In this role, MPAs are considered to be capable of providing insurance as a hedge against fishery failure resulting from the many weaknesses and the multiplicity of uncertainties that afflict fish, fishing and fisheries management systems. The recent World Summit on Sustainable Development (WSSD) Plan of Implementation (POI) called for sustainable fisheries embedded in sustainable ocean ecosystems, but achieving this requires operational action on the extent to which fishing is permitted to affect high-profile species, habitats and ecosystems, as well as the exploited species themselves.

The WSSD POI proposes integrated oceans management as the guiding principle through which sustainability of the oceans may be achieved. Such integration will only be efficient if it is based on a framework of spatial management that fully involves all stakeholders and conservation objectives. In this framework, MPAs may be identified and managed as one important tool to meet the multiple objectives of fisheries, other

economic uses including tourism, transportation, energy and mineral uses, and biodiversity conservation.

While most fisheries sustainability issues can be resolved in a variety of ways, the use of MPAs is an efficient and effective way of simultaneously achieving a number of fisheries and biodiversity conservation objectives in most ocean ecosystems. The extent to which MPAs will 'work' for a fishery and for conservation depends on the objectives set by the stakeholders and managers. The effectiveness of an MPA depends on the quality of the design and management processes that surrounds the MPA, and particularly so for the important potential fishery benefits of stock management and ecosystem offsets.

Designing MPAs to meet dual fishing and conservation objectives requires a strong cooperative interface between conservation and fisheries agencies. With agreement on joint objectives, implementation and management, MPAs can achieve the double payoff —benefits for both fisheries and conservation. Modern optimisation decision-support tools and approaches are available to assist with the technical complexities of such design problems, and MPA designs will be most successful when they are based on rigorous scientific principles.

Achieving successful dual-objective MPAs requires:

- articulation of a succinct 'end game vision' for dual-objective MPAs across a range of types of jurisdictions, including nested policy and implementation arrangements;
- integrated institutional arrangements (including partnerships) for dealing with the design and implementation of MPAs at the regional, national and sub-national (fishery) levels;
- analysis and documentation of the costs and benefits of MPAs in case studies of MPAs that have been designed to provide benefits for both regional conservation and fisheries;
- a program to assess the regional conservation biodiversity benefits that are derived from a range of the types of existing MPAs created for fisheries purposes.

1. Introduction

There has been a recent surge of interest in Marine Protected Areas (MPAs) in fisheries, driven by theoretical assessments of the likely value of protected areas, their potential role in preventing fishery crashes, and their potential role in a wide range of fisheries in mitigating the adverse impacts of fisheries on habitats and non-target species (see for example Sumaila et al. 2000). In a recent analysis of an 'ecosystem approach to fisheries' (EAF), the FAO recommends protected areas as an adjunct to existing fishery management tools, and identifies a series of benefits and issues associated with the use of protected areas in fishery management (FAO 2002).

Marine Protected Areas

A Marine Protected Area (MPA) is "any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment" (Kelleher 1999). The term MPA is equivalent to 'marine reserve', and is used by the World Conservation Union (IUCN) (Kelleher 1999) to refer to seven categories of protected areas with different primary objectives (Table 1). All of these types could be used for fisheries management purposes even though, in most cases, this would not be the primary objective of the MPA. Implicit in the IUCN classification system is the recognition that reserves that are managed for sustainable use can also make an important contribution to biodiversity conservation goals in a region.

In Australia, the IUCN reserve categories have been defined (in the national Environment Protection and Biodiversity Conservation Act 1999) for use in a national marine protected areas program. A different numbering system applies under Australian law (see p.334, EPBC Act 1999)

Table 1. Summary of the IUCN Protected Area Management Categories (Eagles et al. 2002).

Category		Description
IA	Strict Nature Reserve	Managed mainly for science
IB	Wilderness Area	Managed mainly to protect wilderness qualities
II	National Park	Managed mainly for ecosystem protection and recreation
III	Natural Monument	Managed mainly for conservation of

		specific natural features
IV	Habitat/Species Management Area	Managed mainly for conservation through management intervention
V	Protected Landscape/Seascape	Managed mainly for landscape/seascape conservation and recreation
VI	Managed Resource Protected Area	Managed mainly for the sustainable use of natural ecosystems

"No-take" reserves, where all forms of extraction are prohibited, are most likely to be established in MPAs of either IUCN Category IA or IB or Category II*. MPAs may also consist of more than one IUCN category, through the use of zones. For example a critical habitat may be protected by an IUCN Category IA zone, surrounded by a Category II National Park area, which is then surrounded by a larger Category VI Managed Resource Protected Area.

By 'Marine Protected Area' we mean a marine area protected from some or all forms of exploitation and human intervention. An MPA may be closed to all forms of fishing all year round, and if it is also closed to other forms of exploitation and major disruption as well, we consider it to be a "no take reserve". A "no take" reserve may allow entry of people for passive activities such as nature appreciation, surfing or sailing, etc. provided that the activity and any associated infrastructure for such activities does not have any substantive impact within the "no-take" reserve. The crucial feature, however, is that these areas are "no take" and fishing and collecting of flora or fauna, and removal of the substrate are prohibited.

All recent analyses of the issues in global fisheries management have identified "no-take" reserves as having, potentially, a crucial role in providing support for fish stocks, and providing an insurance hedge for the uncertainties in fisheries stock assessments. "No-take" reserves are also widely identified (e.g. Pauly et al. 2002) as a key ingredient in the mixture of measures that is needed to re-direct world fisheries towards 'sustainability'. The increasing non-sustainability and decline of global fisheries (Watson & Pauly 2001, Pauly et al. 2002, Figure 1) is considered by many to be related in part to 'technology creep', where new electronics, bigger vessels, and more efficient fishing techniques increase effective fishing effort and open up new fishing grounds. This increased fishing effort reduces the *de facto* refuges where previously some portion of the fish stocks took shelter, and simultaneously masks the signals of non-sustainability to managers by

* We refer to Category II areas which are gazetted as "no take" in a Plan of Management. This does not include those Category II areas which allow for subsistence indigenous fishing, hunting or collecting. Note that there are variations in the interpretation of the activities that should be permitted within the IUCN categories in some countries.

keeping catches at a high level. In the new fisheries paradigm, explicit reserves replace the *de facto* reserves in the management of such fish stocks (Pitcher 2001).

Fisheries management has a long history of dedicating reserves for specific purposes. These reserves range from short-term closures of a fishery to protect a sensitive spawning period or locality, to permanent closures to specific gear types to protect a particularly sensitive life stage, such as juveniles in seagrass beds. In some coastal fisheries, for example, some habitats, such as seagrasses and near-reef areas, are recognised as too sensitive for trawling. Also, the traditional practice in some small coastal and island communities is to have specific places and times where fisheries are closed. Such closures, when taken together with the natural refuges historically afforded to species that cannot be fished with traditional gear types, have provided *de facto* refuges for many fish stocks.

The contemporary technical research on reserves has been focused on the 'reserve effect'—the effect in and adjacent to a reserve from removing all forms of exploitation. The reserve effect is crucial to delivering reserve benefits to fisheries, but it is only one aspect of a much more complex problem. The interaction of fishery closures with broader conservation has yet to be widely examined, particularly taking account of reserves other than permanent closures. In addition, the spatial scale of reserves required to provide substantive benefits to a fishery, and the interaction of other users both within reserves and in adjacent areas, have been little considered.

In this paper we discuss the principles behind the use of reserves in fisheries management, review the use of reserves within fisheries sustainability systems, and explore some examples of the use of reserves of different types in specific fisheries applications. In looking beyond the reserve boundaries, we review the broader context of reserves for fisheries sustainability, and identify mechanisms through which fisheries may be able to work with conservation agencies and community and industry stakeholders to identify and implement MPAs of different types to achieve the 'double payoff'—benefits for both fishing and conservation.

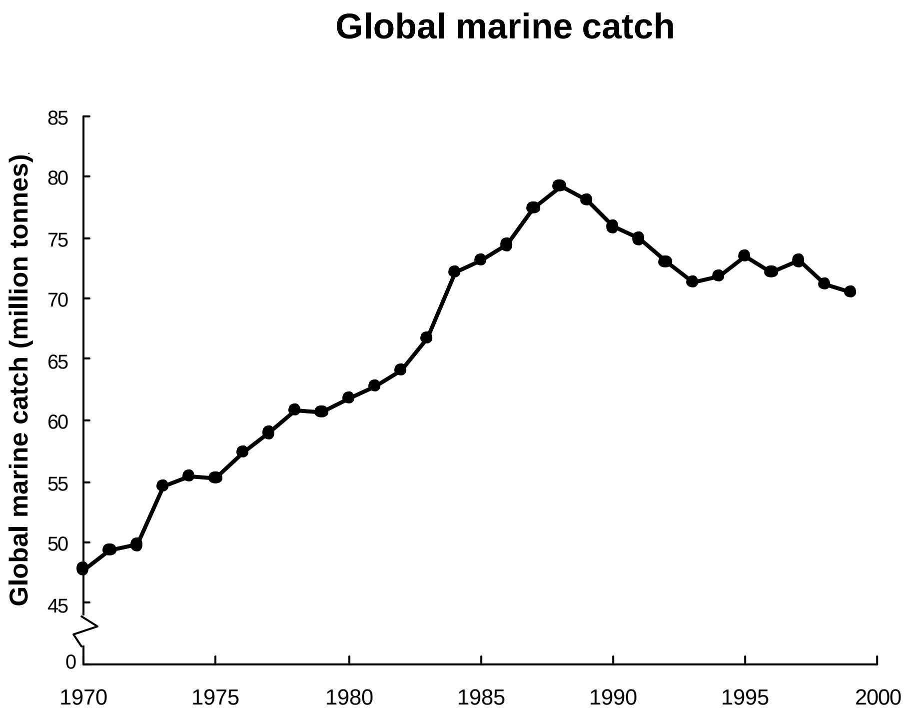


Figure 1
Estimated global fish landings for the period 1950 to 1999, corrected for over-reporting of China catch and without the catch of Peruvian anchovetta (Watson et al. 2001).

2. Policy Contexts

The World Summit on Sustainable Development in Johannesburg (2002) declared: **"***Oceans, seas, islands and coastal areas form an integrated and essential component of the Earth's ecosystem and are critical for global food security and for sustaining economic prosperity and the well-being of many national economies, particularly in developing countries. Ensuring the sustainable development of the oceans requires effective coordination and cooperation, including at the global and regional levels, between relevant bodies, and actions at all levels…"*(section 29 of the Plan of Implementation)

The WSSD Plan of Implementation proceeds to endorse (S29 (d) (e) and (g)) the 'ecosystem approach' as embodied in the Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem (2001)—integrated, multidisciplinary and multisectoral coastal and ocean management; and programmes at the regional and subregional levels aimed at the conservation and sustainable management of fishery resources.

The WSSD POI also calls for (S31) *"the conservation and management of the oceans through actions at all levels, giving due regard to the relevant international instruments* *to (a) Maintain the productivity and biodiversity of important and vulnerable marine and coastal areas, including in areas within and beyond national jurisdiction*", and "(c) *Develop and facilitate the use of diverse approaches and tools, including the ecosystem approach, the elimination of destructive fishing practices, the establishment of marine protected areas consistent with international law and based on scientific information, including representative networks by 2012 and time/area closures for the protection of nursery grounds and periods, proper coastal land use; and watershed planning and the integration of marine and coastal areas management into key sectors*".

The WSSD POI makes it clear that to achieve global sustainability the primary approach to management of the coastal oceans should be based on the integration of spatially-based management systems. The POI sees this being achieved through improved global, regional and local integration of sector arrangements and activities. Marine protected areas, considered as an integrated component of oceans management, are envisaged as one tool to assist to deliver global oceans sustainability.

The WSSD call for integrated oceans management is a response to global concerns that have developed through the past two decades about, broadly speaking, the ineffectiveness of the existing oceans management systems and of the many global and regional agreements and conventions in securing a reduction in the undesirable consequences of fishing (and other activities in the oceans). These global policy foundations have been established, amongst many others, by the UN Convention on the Law of the Sea, and the Convention on Biological Diversity (CBD), but they have provided little operational guidance about how to achieve their various goals and objectives.

For example, the Jakarta Mandate on Marine and Coastal Biological Diversity of the CBD (http://www.biodiv.org/programmes/areas/marine/background.asp), provides policy guidance on protected areas, the precautionary approach, scientific knowledge, indigenous knowledge, stakeholders' participation, and provides support for integrated management. However, because of the complexities involved, the Jakarta Mandate offers little operational guidance, this being left open to interpretation of each relevant party to the CBD.

Similarly, the FAO Code of Conduct for Responsible Fisheries (<http://www.fao.org/fi/agreem/codecond/codecon.asp>) calls for a range of responses to the issues confronting global fisheries, but offers little operational guidance. As a result, the ecosystem aspects (in particular) of the FAO Code have not been widely implemented in fisheries.

A lack of appropriate management is considered to have contributed to a decline of some fished species, fishery crashes, ecosystem changes, and the decline of some non-target organisms affected by fishing operations (Hutchings 2000, Pitcher 2001, Pauly et al. 2002). Sectoral management, which is focused on specific ocean uses or activities, such as the fishing sector, generally has not responded adequately to use-related issues, such as the impacts of fishery bycatch, or the incidental capture of mammals or seabirds in fisheries. The integration of ocean management calls for all uses to recognise conservation objectives and the specific interests of a range of users, and to respond to constraints that may be external to their sector. An increasing level of integration, in the sense of aligning all policies and practices that may affect an ocean area, is a measure of the maturity of a management system (Winsemius 1995). Increasing integration is developed as sector-based management gives way to integrated spatially-based management that covers all users of an ocean area and respects the conservation values of ecosystems and species.

At the national level, a number of jurisdictions have recognised the critical need for change in fisheries management policies, and many of these involve a role for fishery reserves. The US Committee on Ecosystem Management for Sustainable Marine Fisheries (US National Research Council 1999), the Ecosystem Principles Advisory Panel (NMFS 1999) and the US Committee on the Evaluation, Design and Monitoring of Marine Reserves and Protected Areas (NRC 2000) have all identified an important role for various forms of protected areas in supporting ecosystem-based fishery management, and delivering the benefits of 'more sustainable fisheries and marine ecosystems, as well as more economically-healthy coastal communities' in the US (NMFS 1999).

Australia's Oceans Policy, established in 1998, calls for an integration of management within Australia's 200 nautical mile Exclusive Economic Zone (EEZ) using ecosystem-based management principles. Regions of the EEZ, determined using biogeomorphic criteria, have been established as the basic spatial unit of management. Within each region, a marine plan is expected to integrate the policies and practices of all industry sectors, governments and stakeholders to ensure that activities are sustainable and that specific targets for conservation and sustainable use are achieved. This includes the goals and objectives of Australia's Fisheries Act and the Environment Protection and Biodiversity Conservation Act, and national policies such as the National Representative System of Marine Protected Areas (NRSMPA), the National Strategy for Ecologically Sustainable Development and the National Strategy for the Conservation of Australia's Biological Diversity.

Under Australia's *Fisheries Management Act 1991*, the Australian Fisheries Management Authority's responsibilities include:

> *"ensuring that the exploitation of fisheries resources and the carrying on of any related activities are conducted in a manner consistent with the principles of ecologically sustainable development and the exercise of the precautionary principle, in particular the need to have regard to the impact of fishing activities on non-target species and the long term sustainability of the marine environment".*

The Oceans Policy has been specifically designed to provide for integration of policies and practices across and within sectors, to assist the various industry sectors to be more sustainable in their activities. The Oceans Policy asserts that integrated management of multiple uses of ocean resources is a principle of ecologically sustainable oceans use applicable to all decisions affecting the use of Australia's marine resources. While the

Oceans Policy has been in place since 1998, progress at achieving integration of management activities has been slow (Alder & Ward 2001).

One specific aspect of the integration problem is the need for reserves, which are called for under the NRSMPA to achieve conservation objectives. While the *Fisheries Management Act* does not require a fishery to implement reserves, controls to achieve specific fishery outcomes are often applied as spatial controls, and as a mixture of spatial, temporal or gear constraints, to achieve specific fishery objectives such as the maintenance of spawning biomass. In this sense, there is a commonality of purpose in the fisheries closures and the NRSMPA reserves—both intend to conserve specific aspects of biodiversity, although they may be expecting to achieve different objectives through the closures. In this sense, Australia's Oceans Policy is working with the Australian *Fisheries Management Act* (and others) to identify and implement reserves and other arrangements that will assist in achieving sustainability in Australia's EEZ.

Several technical analyses of the problems of global fisheries (Pauly et al. 2002, Roberts et al. 2001, Ward et al. 2001, Pitcher 2001) have identified reserves as an important tool that should be used to adjust fisheries so that they can become genuinely sustainable, in fisheries terms. These arguments for reserves are sometimes based, amongst others designed to correct fishery issues (Pauly et al. 2002), on the provision of adequate insurance for the weaknesses in modern fishery management practices and the multiplicity of uncertainties that afflict fish, fishing and fisheries management systems. While these weaknesses are certainly of broad concern, the imperative to ensure sustainability of the oceans ("*the conservation and management of the oceans through actions at all levels*"—the terms of the WSSD) entails more than only ensuring the ongoing capacity of fisheries to catch fish.

Achieving sustainable fisheries operating within sustainable ocean ecosystems (the context of the WSSD declaration) will involve a range of judgements about the extent to which fishing is permitted to affect habitats, high-profile species, ecosystems, as well as the exploited species themselves. The implementation of the WSSD proposes integrated oceans management of all the ocean values and uses as the guiding principle through which sustainability of the oceans may be achieved. The use of reserves as a tool by more than one sector to achieve specific sectoral objectives as well as integration objectives is both an opportunity and a challenge. Different sectors (such as fishing and conservation) will often have different operational objectives—the opportunity is to secure agreed and effective reserves that will deliver on integrated objectives; the challenge is to design reserves that will simultaneously meet these sometimes opposing sets of objectives.

In the context of marine reserves, it is clear that achieving an integration of management systems across the different sectors can only be based on a framework of spatial management. First, reserves themselves are always defined spatially, even when the main control feature is a temporal closure. The legal definitions of marine reserves are universally specified in two dimensions (spatial coordinates) and include the third dimension as some or all of the overlying waters and in some cases, the seabed to a specified depth and the airspace overhead to a specified altitude. Second, management of closures is now achievable through modern vessel movement monitoring systems and large-area surveillance systems that are land or satellite-based. Third, the scientific basis for reserve design and optimisation has been developed for spatially defined systems representative of habitats, ecosystems or bioregions. Fourth, many users, including fishers, use a spatial framework to manage the activities within their sector.

It is therefore clear that achieving sustainability through integration in oceans management, for reserves and other objectives, is best achieved through adoption of a system of spatial management that is integrated across the various users and conservation objectives. In this framework, reserves would be established and managed to meet multiple objectives, particularly including fisheries and conservation. Other relevant sectors that would also benefit from such an arrangement are tourism, oil and gas, and transport, because establishment of an agreed set of reserves would provide for increased certainty in their business operating environments, and at least for tourism, the low-impact non-extractive tourism in reserves may provide an additional resource. The research sector would benefit through the preservation of reference sites.

Given careful design, reserves may also be able to provide benefits to fisheries in terms of an offset for the impacts of fishing on sensitive habitats and species, the provision of reference sites, and may also assist with stock management concerns.

3. Sustainability Strategies

Although there are a range of global, regional and national policies that call for improvements in fisheries management to meet the objectives of ocean sustainability, these strategies do not provide the detailed mechanisms to enable implementation in any specific sector. They also only provide the broadest guidance for how to deliver the required spatial integration across sectors. For example, Australia's Oceans Policy provides for the development of Regional Marine Plans, which are based on regions established to reflect ecological and physical variability, but includes little useful detail of how these plans will achieve integration and act to improve sustainability. Without clear operational guidance, achieving sustainability is likely to be difficult.

In countries trying to develop a national framework for an integrated cross-sectoral ecosystem approach to ocean management, like Australia, effective integration is needed across sectors, as well as at the finer scale within sectors. To date most efforts globally to develop an ecosystem approach to management have been focused at the finer scale of within individual fisheries. While it has been recognised that other sectors such as marine tourism, shipping and mining also need similar operational guidance, the global failures in fisheries management have attracted the most attention.

In determining the 'ecosystem approach' to fisheries, the FAO (FAO 2002) has proposed to broaden the intent of existing fisheries management systems to take account of ecosystem concerns. The FAO guidelines on the Ecosystem Approach to Fisheries

(EAF) adopt the framework of ecosystem-based management that were proposed earlier for global fisheries by Ward et al. (2002) following ecosystem management models used in a range of terrestrial situations.

The FAO guidelines acknowledge that under an EAF approach, marine reserves are likely to be more commonplace, and to be established to meet a range of stakeholder expectations, not simply a set of narrow fishery management objectives. However, in the EAF approach, the core decisions about sustainability, such as which areas should be reserved or what forms or fishing will be permitted or excluded to meet biodiversity conservation objectives, are to be determined using existing stakeholder processes and arrangements. This follows from the approach by FAO to EAF, which is that EAF is to be entirely an extension of the existing fisheries management system, and should not involve new or novel initiatives. The FAO EAF approach is yet to be supported by all governments, and there appear to be a number of significant obstacles to be resolved that are unrelated to the potential value of marine reserves.

Unfortunately, as well recognised by a number of recent technical analyses, and expressed in fishery crashes (Pitcher 2001, Pauley et al. 2002), the track record of existing fisheries management approaches is not good, even in data-rich fishery situations. Often the failure is not in the lack of data, but in the lack of effective control or commitment of all parties to react to the data, or to the creep of fishing technology, and the lack of the management system to competently adapt and adjust in a timely way to such problems. It therefore seems unlikely that EAF will be able to be effective without new global policy initiatives and imperatives that flow into national legislation and consequent changes to local fishery activities to make such policies operational. In keeping with the call from WSSD, such initiatives should move towards integrated systems of ocean management, and include reserves as tools to deliver on regional conservation objectives as well as assist to manage fisheries and their impacts.

Recognising the need for an integrated global policy approach to fisheries management, Ward et al. (2002) analysed the key issues from both conservation and fishery perspectives, and identified a series of operational activities that could be applied within a fishery to help to improve their sustainability. The integration component is achieved through a full engagement with other users and stakeholders having an interest in the areas where the fishery operates, or in resources or species that the fishery may affect, to achieve objectives that are agreed with stakeholders for ecosystems, species, habitats and the exploited species.

The Principles of Ecosystem-based Management proposed by Ward et al. (2002) to guide the development of sustainability in fisheries are:

1. Maintaining the natural structure and function of ecosystems, including the biodiversity and productivity of natural systems and identified important species, is the focus for management
2. Human use and values of ecosystems are central to establishing objectives for use and management of natural resources

3. Ecosystems are dynamic; their attributes and boundaries are constantly changing and consequently, interactions with human uses also are dynamic
4. Natural resources are best managed within a management system that is based on a shared vision and a set of objectives developed amongst stakeholders
5. Successful management is adaptive and based on scientific knowledge, continual learning and embedded monitoring processes.

An operational approach to Integrated Ecosystem-based Management of fisheries, to be successful, would (from Ward et al. 2002):
1. Operate within a supportive policy framework
2. Recognise economic, social and cultural interests as factors that may affect resource management
3. Recognise ecological values and incorporate them into management
4. Provide adequate information on utilised species to ensure that overfishing is a low risk
5. Ensure that the resource management system is comprehensive and inclusive, based on reliable data and knowledge and uses an adaptive approach
6. Properly consider environmental externalities (cross-sectoral impacts) within the resource management system.

To implement this integrated and ecosystem-based approach to management at an operational level, a typical coastal fishery in a developed country would:
1. Identify the stakeholders—the interested parties in the fishery
2. Prepare a map of the ecoregions where the fishery operates, including species, habitats, coastal and oceanographic features
3. Identify the partners and their interests—the most vitally interested stakeholders that are directly interested or affected by the fishery (key conservation and other government agencies and fishing industry and community leaders)
4. Establish, through involvement of conservation agencies, researchers and other partners and stakeholders, the ecosystem values of the ecoregions, considering habitats, species and uses
5. Determine the main potential hazards the fishery might pose to the ecosystem values
6. Conduct an ecological risk assessment that will determine the actual risks from the fishery and other users, and the priorities for resolving gaps in knowledge
7. Establish the objectives and targets—agree with partners on specific operational goals (targets and reference points) for the ecosystem and the fished stocks
8. Establish strategies for achieving the targets (which may include establishment of reserves to offset fishery impacts)
9. Design the information system—including monitoring systems for stock and ecological indicators
10. Establish information needs and research priorities
11. Design performance assessment and review process
12. Design and implement an EBM training and education package for fishers and managers.

The intention of the ecosystem-based approach is to provide a management framework where conservation objectives can be determined and implemented by fisheries in close co-operation with the key stakeholder partners, and provide for an effective mechanism for achieving integration of management. Reserves will be an important component of this integration, and will probably result in protected areas of various levels of protection, designed to deliver specific outcomes to fisheries and for broader biodiversity conservation. The EBM approach (Ward et al. 2002), like the EAF approach, does not specify targets or benchmarks for conservation objectives, but the EBM approach is more likely to achieve effective conservation outcomes through its focus on ecosystem integrity and quality and its extensive stakeholder engagement through new structural consultative arrangements.

For the operational implementation of EBM new structural arrangements are likely to be needed because, in many marine areas, there are multiple fisheries harvesting many species of fish, crabs and prawns using a variety of fishing methods. Therefore, in adopting an EBM approach, one of the crucial management questions facing fisheries agencies is whether to attempt to manage a diverse set of fisheries that have a large overlap in the areas fished as a single integrated management entity. The term “super-fishery” has been coined to apply to this concept (Bohm 2002).

In Australia, for example, the Australian Fisheries Management Authority (AFMA) recently has merged four of Australia’s most important offshore fisheries under a single new management regime that will be known as the Southern and Eastern Scalefish and Shark Fishery (SESSF). The combined SESSF fisheries will cover an area that includes nearly half of the waters within the Australian Fishing Zone, more than 4 million km^2. The merger of these fisheries to create Australia’s first ‘superfishery’ offers the obvious potential advantages of managing the individual sectors under common goals and objectives to ensure that the cumulative effects of all the sectors are ecologically sustainable.

In creating such ‘superfisheries’ the key question for fisheries agencies is whether this type of merger will create a management regime that is too large, complex and cumbersome for the fishers, fisheries managers and other stakeholders to understand and support. In many countries the situation is further complicated by multiple fisheries that overlap national and sub-national jurisdictional boundaries in the absence of clear legal agreements to guide inter-jurisdictional integration. Success in merging fisheries management regimes to achieve more effective and efficient EBM is likely to depend heavily both on the commitment of the key participants and the quality of the consultative arrangements—matters which usually are closely inter-related.

An alternative approach that may achieve the same aims is to manage the individual fishery sectors using the EBM operational approach and implementation mechanisms outlined above, but form a co-ordinating group of key participants who become responsible for ensuring that cumulative impacts within the common fishery region meet agreed ecological standards and targets.

Deciding whether to create a ‘superfishery’ or a strong coordination structure requires a careful assessment of the size, complexity and nature of the individual fisheries that operate within a region. Both approaches require procedures to establish agreed ecosystem objectives and targets, and strong commitments by both industry leaders and the management agency to achieving ecological sustainability in the use of fisheries resources.

If implemented effectively, either approach can offer substantial advantages to the fishing industry in defending against criticism from other sectors or interests, or in criticising the ecosystem impacts of other sectors on fishing interests. Either approach would place the fishing industry in a strong position to accurately describe its impacts and the measures it is taking to achieve ecological sustainability and to request that other sectors take similar measures to ensure that the cumulative impacts of all users are ecologically sustainable.

As noted elsewhere in this paper, well-designed MPAs are likely to be a key management tool that can provide benefits across several fisheries that share common fishing grounds, as well as provide benefits to other sectors engaged in sustainable use of the same area. It is for this reason that MPAs can be considered to be an important tool to support the integration of ocean uses, and support sustainability of the oceans.

4. Dual Objectives–the Double Payoff

Modern concepts of fishery sustainability incorporate aspects of ecosystem protection, and fisheries are increasingly being required to demonstrate their lack of impacts in marine systems in order to be permitted to continue to fish. In other words, fisheries are being expected to take a more active part in ecosystem management issues, many of which may be the primary responsibility of other agencies or other sectors. Where it is difficult to demonstrate that fishing can be conducted with only minimal impact on non-target organisms and habitats, no-take MPAs offer fisheries managers an opportunity to work in partnership with other agencies, industry organisations and community groups to provide for the conservation of species and habitats that may otherwise be affected by fishing.

No-take MPAs provide a fishery with an efficient tool to provide for protecting non-target species and habitats, and if the no-take areas are designed correctly, they could simultaneously provide support to the target species and possibly the fishery. By protecting non-target species and habitats from the effects of fishing, fisheries can rightly claim to be supporting conservation objectives for the region, and be able to appropriately reject spurious claims of high levels of environmental damage by a fishery. This situation also could assist a fishery to avoid very expensive and long term research programs designed to fully evaluate environmental impacts within fishing grounds, provided that non-target species and habitats are reasonably represented in no-take areas. Where dual objectives were being achieved, a fishery could appropriately claim to be delivering the 'double payoff', where both conservation and fishing achieve benefits (Sanchirico & Wilen 2001).

In many situations, MPAs are being initiated by conservation agencies to meet specific objectives for nature conservation. In Australia, a national program has embarked on securing a comprehensive, adequate and representative (CAR) system of marine protected areas for conservation purposes (the National Representative System of Marine Protected Areas—ANZECC 1999). Although this NRSMPA network is also intended to provide support for sustainable use of fishery resources, the design process has not explicitly taken fishery values into account, so that the protected areas declared to date may not provide much support, if any, for fisheries. However, fisheries managers and industry representatives are increasingly engaging in integrated marine planning initiatives within the various Australian jurisdictions, which include programmes to declare new MPAs. For example, the Department of the Environment and Heritage, the National Oceans Office and the Australian Fisheries Management Authority are cooperating to design a system of representative MPAs as part of Australia's South-east Regional Marine Plan. It is intended that where possible these MPAs will contribute to the sustainable management of fisheries. In addition, a research program is underway between the Australian Northern Prawn Fishery and the Department of the Environment and Heritage to design marine protected areas capable of delivering the "double payoff", and in the future these reserves may be included within the NRSMPA.

If MPAs are to meet multiple sets of objectives, then it is clear that they must be designed using selection criteria that reflect these multiple objectives. The success of MPAs for biodiversity conservation is well understood to depend on the quality of the design process (Halpern & Warner 2002), including the use of specific selection criteria (Day et al. in press). Models have been used to explore the interaction between a typical set of both conservation and fishery objectives, and there may be scenarios where the two different types of objective may not be in conflict, but be complementary, subject to the details of the design process (Hastings & Botsford 2003). The success of no-take areas for fisheries objectives alone is likely to be similarly critically dependent on the design process (Mayfield et al. 2000, Acosta 2002, Gerber et al. 2002),

For MPAs to provide effective support for a fishery, the design criteria need to be based on the specific biological characteristics of the target species, because their life history characteristics may have a major influence on the effectiveness of a reserve in supporting a fishery (Sumaila 1998, Sanchirico & Wilen 2001). The rate of transfer of exploited species between reserves and fished areas appears to be of particular importance (Tuck & Possingham 2000, Sanchirico & Wilen 2001). However, simple models of reserve implementation suggest that designs that will achieve the 'double payoff' may need to use parameters and criteria that are relatively complex, to avoid the risk of failing to simultaneously achieve both conservation and fishing objectives (Gerber et al. 2002).

To date, only a limited number of MPA programmes have been undertaken to optimise a set of no-take areas to jointly achieve both outcomes for conservation and outcomes for fisheries. (The Great Barrier Reef Marine Park Authority is establishing a set of no-take areas throughout the Great Barrier Reef World Heritage Area, and these are designed through an optimisation approach to secure representative samples of the biodiversity and simultaneously minimise disruption to fishing activities in the World Heritage Area (Day et al. in press). Multiple criteria analysis has been used in the Asinara Island National Marine Reserve to assign zones for specific levels of protection, and to minimise disruption to traditional fishing practices (Villa et al. 2002). An optimisation approach to designing a series of no-take reserves for the Gulf of California is also described by Sala et al. 2002, where a network of reserves is proposed that will provide for conservation of biodiversity and simultaneously complement management of the fisheries.

5. The Main Benefits

Marine Protected Areas provide benefits to both fisheries and conservation. The main benefits that have been traditionally derived by fisheries from reserves relate to stock enhancement and management, primarily through the key processes of spillover, larval export and the protection of critical habitat. However, responding to the need for more ecosystem-based management, some fisheries now also recognise an additional broad range of benefits based on MPAs that range from ”no take” to “managed resource area” levels of protection (see Table 1).

For fisheries, protected areas generally can be considered to provide four basic types of fishery benefits:

- Support for stock management, including:
  protection of specific life stages (larval nursery grounds)
  critical functions of an exploited population (feeding grounds, spawning grounds)
  spillover of an exploited species
  dispersion centre for larval recruitment of an exploited species
- Support for fishery stability
- Ecological offsets—trade-off for ecosystem impacts
- Improved socio-economic outcomes for local communities.

5.1 Stock Management

5.1.1 Spillover

Spillover is the export from a protected area to adjacent unprotected areas of young and mature fish, which may be of a size that can be taken in a fishery. Spillover is thought to occur mainly as a result of the effects of increasing densities and sizes of the individuals within the protected area, which results in a proportion of the population moving across the boundaries of the protected area, in search of shelter, for food, or for reproduction purposes. The phenomenon of spillover is well documented (Ward et al. 2001) and is thought to be the main process that underpins the well known behaviour of ‘fishing the line’, which is where fishers congregate at the boundaries of a protected area to fish, expecting greater fishing success. Kelly et al. (2000) show that in New Zealand, this has been a successful strategy in fishing for lobsters near three no-take reserves. This may assist a fishery by reducing searching time, and by providing more abundant and larger fish (since reserves are a source of older animals). Of course, the design of a no-take reserve needs to ensure that periodic movements (such as daily feeding excursions) will not expose a target species to fishing, and that the catch of a species taken 'on the line' is indeed based on spillover.

5.1.2 Larval export

Larval export is the export from a protected area of the reproductive propagules of an exploited species, resulting from the increased number and reproductive capacity of breeding individuals in the reserve. This can be considered as a 'seeding effect', where eggs or young juveniles move from a protected area into other areas, some of which may be very distant from the protected area depending on currents and seasonal climatic factors. Assuming that there is available habitat, and other conditions are appropriate, these propagules eventually settle and may ultimately contribute to the exploited population in a fishery. The magnitude of the contribution of larval export from a reserve into a fishery is difficult to measure empirically, and although there are some data most are of questionable general validity (Palumbi 1999) and the considerable modelling that has considered this question is of limited application. Nonetheless, there is now increasing evidence that some fishery closures have generated larval export at a scale that would provide support for a fishery (Gell & Roberts 2003)

BOX 1

The spillover effect in commercial and recreational fisheries

The Merritt Island National Wildlife Refuge at Cape Canaveral, Florida, USA, contains two areas that have been closed to fishing since 1962 - the Banana Creek Reserve and the North Banana River Reserve. Like many areas closed for national security, defence, or other military purposes, these areas were not chosen for the purposes of biodiversity protection or fisheries enhancement. The two estuarine areas that make up the refuge are closed to public access for the security of the nearby Kennedy Space Center, and have a total area of $40km^2$. Before these areas were closed, there was intensive commercial and recreational fishing effort in the area and fish stocks were heavily exploited. Between 1957 and 1962, an average of 2.7 million kilograms of fish was landed annually in the vicinity of Merritt Island by 628 commercial fishers, and a further 1.47 million kilograms landed by an average of 764,000 sport fishers (Gell & Roberts 2003).

The value of this reserve for the adjacent recreational fishery has been assessed by examination of the number of record-size ('trophy') fish caught by recreational fishers. The area enclosing 100 km to the north and south of the reserve was found to provide 62% of record-size black drum, 54% of red drum and 50% of spotted seatrout. The area considered comprises only 13% of the Florida coast, and the habitats found in the Merritt Island National Wildlife Refuge are found in many other parts of Florida (Gell & Roberts 2003). Since the mid-1980s most Florida records for black drum and red drum have been recorded from the vicinity of the Merritt Island Refuge. Fish tagging studies show that these species move out of the reserve and into surrounding waters, and this, together with the evidence of record sizes, is evidence for a substantial level spillover of these fish from the reserve into the adjacent recreational fishery.

BOX 2

Area protection and fisheries on Georges Bank

The fisheries for groundfish – species living closely associated with the seabed – on the US and Canadian Georges Bank in the north-west Atlantic Ocean were once one of the most productive in the world. After decades of intensive fishing the stocks of several of these species, including cod and haddock, declined and eventually collapsed in the 1980s and early 1990s. Overfishing and the impact of intensive scallop dredging on juvenile stages of the groundfish and their habitats were considered to be the major causes of the fishery crashes.

In 1994 in the US waters of Georges Bank and Southern New England, three large areas of about 17,000km^2 of historic importance to groundfish spawning and juvenile production were closed to any fishing gear capable of retaining groundfish (trawls, scallop dredges, gill nets, hook fishing). In the following 5 years, the closed areas significantly reduced fishing mortality of protected groundfish stocks. The location of the reserves also provided year-round protection to the stocks of sedentary fishes, primarily flounders, skates, miscellaneous other fish, and bivalve molluscs. The closures afforded less protection to migratory age groups of cod and haddock, but additional fishing regulations in the fished areas and in the Canadian parts of Georges Bank contributed to stock-wide reductions in fishing mortality. The have not yet recovered, but There are encouraging, if early signs from the reports of fishers and from research surveys that stocks of cod are recovering from their former highly depleted condition (Gell & Roberts 2003).

As a result of the reserve, by 1998 the harvestable scallop biomass was 14 times denser in the reserves compared to the fished areas. Parts of one closed area were opened to scallop dredging in 1999, but restrictions on gear and the areas fished were used to limit the impact on gravel substrates, limit the by-catch of groundfish, and minimise the impact on juvenile cod and haddock. Results from these re-openings have encouraged managers to contemplate a formal 'area rotation' scheme for scallops intended to improve overall yield in the scallop fishery. The overall impact of this rotational harvest approach on groundfish stocks is unclear.

In a related area, in 1987 about 13,700 km^2 associated with 2 offshore banks on the continental shelf of Nova Scotia, Canada (adjacent to Georges Bank) were closed to commercial trawling for groundfish in order to protect the juvenile stages of haddock. The closures were implemented in stages by reducing gear types permitted to fish on the banks, until 1994, when all fishing was prohibited because of the collapse of stocks of cod and haddock in the region. The reserve resulted in a change in the fish composition and an increase in numbers and sizes of several commercially important species in both the reserves and also in an adjacent fished area. Haddock are only now beginning to respond to the area closure. The effects of the reserve on the adjacent fished area are thought most likely to be caused by spillover and possibly larval export from the reserve (Fisher & Frank 2002).

Overall, fishery closures of large portions of Georges Bank and adjacent areas have proved to be an important element leading to more effective conservation of a wide range of commercial and non-commercial species, even though the closed areas were selected on the basis of seasonal spawning grounds of haddock and the distribution of yellowtail flounder. There is clear evidence that the MPAs have provided a very important contribution to ongoing restoration of the fisheries in this area (Murawski et al. 2000).

5.2 Fishery Stability

Improving the stability of a fishery is an important operational objective for fisheries managers in most intensively-managed fisheries. The main objective in intensively-managed fisheries is not to establish a constant level of yield from a fishery, but to match the yield to the capacity of the fish population to replenish itself and provide a secure ongoing basis for continuing such yields in future years. Protected areas are considered to be able to increase the stability in a fishery by:

1. helping to maintain a predictable and secure level of yield from a fishery,
2. reducing the total level of effort in a fishery that is either fully- or over-exploited,
3. providing for spillover or larval export that can be considered to be securely linked to natural or broad scale environmental changes but uncoupled from fishery-induced impacts on levels of breeding stock or recruitment etc,
4. providing for unfished reference sites where important parameters in the fishery (such as natural mortality) may be estimated free from the effects of fishing,
5. acting as reference sites where the benchmark environmental conditions can be established so that the impacts of external factors (such as coastal development and watershed management) affecting the fishery and local habitats can be assessed and predicted,
6. assisting with the issue of establishing a secure allocation of access to the fish resource (by forcing an explicit assessment of the resource and its value in the process of protected area design), and finally
7. providing a form of insurance against the effects of unexpected problems that may arise from the existing system of stock management (after Ward et al. 2001).

Simple models of tropical reef fisheries, calibrated against empirical data derived from several specific fisheries, indicate that the global adoption of MPAs in such fisheries could enhance global yield by between 10 and 80% (Pezzey et al. 2000). While such models are limited by assumptions about the extent of fisheries management outside modelled reserves, they indicate that reserves will contribute substantially where fish populations are less than half of their normal (unfished) level.

Coral reef fisheries, because of their parlous condition, have been perhaps the best studied with respect to the effects of MPAs. Since many fisheries, including those considered to be well-managed and sustainable, deplete populations to less than 20% of the unfished level, much of the remainder of the world's fisheries may also be improved through the use of MPAs as fisheries management tools. While the nature and extent of these improvements, including improvements in stability of the fisheries, are difficult to predict and will be different for every fishery, it is highly likely that some level of improvement is available for almost all fisheries, subject to reserve design and the implementation of other complementary and supportive fisheries management controls.

BOX 3
Tropical Subsistence Fisheries
– better socio-economic outcomes and improved stability

In 1995 in St Lucia, West Indies, a network of 4 reserves was created to cover about 35% of available fishing grounds (reef and offshore waters) to attempt to restore a fishery that had no other form of management and was severely over-exploited. Research indicates that the reserves increased the adjacent artisinal fishery catches by 46% for large fish traps and 90% for small fish traps in 5 years, and an overall increase in yield of the fishery. (Roberts et al 2001).

Similar outcomes were achieved in a small-scale fishery in Egypt where, in 1995, in collaboration with local Bedouin and fishermen, five no-take fisheries reserves were established within the Nabq Natural Resource Protected Area, South Sinai, in the Egyptian Red Sea. The abundance, size, structure and catch of commercially targeted groupers, emperors, and snappers were investigated before the establishment of these reserves, then in 1997 and again in 2000. By 1997, these fish had shown a significant increase in mean abundance within two of the reserves. By 2000 each fish family and three individual species had increased in abundance in the reserves. Mean recorded catch per unit of fishing effort within the adjacent fished areas increased by about two-thirds during the 5 years. The establishment of the reserves appears to have played a key role in maintaining the sustainability of the fishery. The involvement of local Bedouin and fishermen in the co-management of fisheries resources was considered to be critical to the success of this initiative (Galal et al. 2002).

5.3 Offsetting ecosystem impacts

The ecological and ecosystem impacts of fisheries (see for example Jennings & Kaiser 1998, Hall 1999) are increasingly being considered in detail as part of the sustainability assessment of modern fisheries. In the global eco-labelling program of the Marine Stewardship Council (Phillips et al. 2003) the performance of a fishery is critically examined to determine if it meets a global sustainability standard that includes the ecosystem effects of fishing. And similarly, under Australia's national legislation (the EPBC Act 1999) fisheries are being assessed, amongst others, on the basis of their ecological impacts on ecosystems. These assessments are consistent with the intent of the WSSD, and with modern interpretations of the need for the management of fisheries to be more ecosystem-based (Ward et al. 2002).

Fishing cannot be conducted without some form of ecosystem impacts, at the very least on the population structure of the species being fished. However, many fisheries also have impacts on ecologically associated species, whether they be on predators or prey of the fished species, on competitors for an ecological resource, or on species that simply co-occur in the area being fished and are affected by either being incidentally caught in the fishing equipment (the bycatch) or have their normal behaviour disrupted by the presence of fishing gear or vessels. Many fisheries also have physical impacts on the habitat where they fish, particularly through low-selectivity gear such as benthic trawls. Protected areas that are designed to offset these problems, by protecting representative habitats, or providing specific refuge for a rare species, can assist a fishery to ensure that unavoidable ecological impacts that are inherent in their activities can be effectively minimised.

The impacts of a fishery can be minimised through a combination of gear improvements, deployment techniques, and through the provision of refuges for populations of species, or habitats, that are affected in the fishing grounds. This approach to conservation invokes a bioregional scale of consideration, and recognises that fishing has impacts in fishing grounds, some of which may be unavoidable, but that bioregional scale conservation objectives can be achieved through an appropriate set of reserves that give refuge to populations of species and habitats that might otherwise be degraded because of the impact of fishing. Protected areas offer the opportunity to offset the impacts of fishing by providing, on a bioregional scale, the opportunity to maintain such populations and habitats. While protected areas will never be able to completely offset the ecological impacts of a fishery, when taken in conjunction with other mitigation activities (such as gear modifications) they can provide a cheap and effective contribution to help offset the overall ecosystem impacts of a fishery.

BOX 4

The Australian Northern Prawn Fishery

The Northern Prawn Fishery (NPF) is Australia's most valuable federally-managed fishery, with an average annual catch of about 8,000 tonnes, worth between AUD$100 and $175 million, taken by 96 modern trawlers. The NPF operates within a 771,121 km^2 area across most of the top of tropical Australia.

The fishery survived the early history of overcapitalisation/overfishing common to most prawn trawl fisheries during the 1970s and early 1980s, when up to 302 trawlers were operating in the NPF. Since the mid 1980s, fishing effort has been greatly reduced through industry-funded buybacks, spatial and temporal closures, and substantial gear (net) reductions. The fishing season has been reduced from the entire year to just over 4 months. The fishery has been highly innovative in addressing bycatch issues, including being the first Australian fishery to voluntarily withdraw from shark fishing, formerly a profitable by-product, in order to protect shark species.

Currently, all known critical juvenile prawn nursery seagrass areas in the NPF are protected from trawling under the NPF Management Plan in what are called Fishery Closure Areas. Continuous Vessel Monitoring System (VMS) surveillance ensures that the closures are protected from trawling. There are 15,830 km^2 of juvenile prawn habitat that mostly could be fished, but is now protected within permanent closure areas, and a further 51,470 km^2 protected within seasonal closure areas. These amount to 2% and 6.7 % of the NPF managed area respectively. While it is to the NPF industry's credit that such extensive areas of prawn habitat are protected from NPF fishing, these areas are not protected from other human activities, including other forms of fishing.

The NPF has recognized that "no take" marine protected areas are an important management tool that can benefit the fishing industry by providing greater protection to critical nursery habitat than can currently be provided by Australian Fisheries legislation, as well as providing refugia for many of the benthic and bycatch species impacted by NPF trawling.

The NPF now has a significant research effort underway with Environment Australia to identify benthic species assemblages, model the performance of existing spatial closures, and identify different reserve configurations that can fully achieve biodiversity conservation objectives, while at the same time maximising the value of the commercial fishery (adapted from Carter et al in press).

5.4 Conservation Benefits

The conservation benefits of protected areas are well established, but in most cases these benefits have been documented only from "no take" MPAs. These benefits have been mainly observed within and adjacent to the "no take" areas.

Protected areas where no exploitation is permitted are widely acknowledged as a highly effective approach to conservation of marine biodiversity (e.g. Roberts & Hawkins 2000). Almost any form of reserve no matter where placed, provided it has a strong and effective management regime, will make a contribution to the conservation of local marine biodiversity. However, those reserves established through a systematic design process will be most effective in achieving the broader goals of conservation, such as protection of the habitat of important species, or protection of representative samples of the typical habitats and species assemblages of a region (Margules & Pressey 2000).

Nonetheless, the history of MPA establishment is that most reserves to date have been established with only limited systematic analysis, or with data that relates, typically, to only a few key species or habitat types. But even these marine reserves can protect species within their boundaries, and improve the condition of biodiversity within a few years of reserve establishment.

An analysis of 80 ”no take” MPAs where there have been reliable data gathered indicates that the reserves were highly effective in improving the conservation of a range of fauna and fauna, and within short (up to 3 years) periods of full protection (Halpern 2003, Halpern & Warner 2002).

Despite their universal role in protecting biodiversity, “no take” MPAs may have a greater value for those species that are exploited than those that are not exploited (Cote et al. 2001) although this will depend on the nature of pressures on ocean ecosystems outside the reserves. Where a ”no take” MPA is located within well-managed ocean ecosystems, the species that will benefit most from establishment of the MPA are those that are exploited outside the ”no take” boundary, but if the ecosystems outside the boundary are heavily exploited and impacted by a range of uses, a “no take” MPA could be expected to provide a much more important level of protection for the full range of biodiversity.

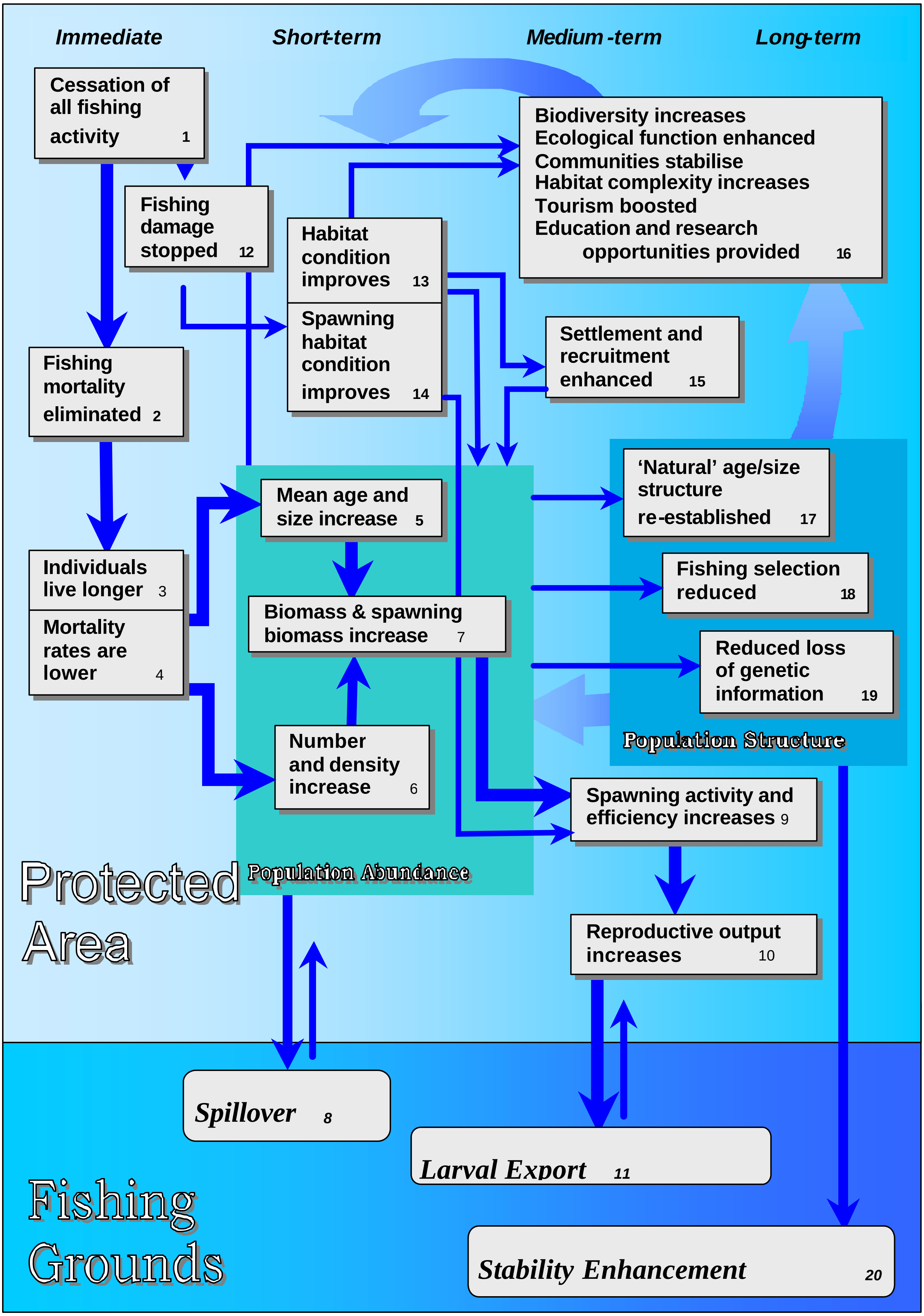
The benefits of “no take” MPAs accrue to a broad range of taxa (Halpern 2003; Table 2), including migratory species (Roberts & Hawkins 2000, Apostolaki et al. 2002). The species richness (total number of species) biomass, size of organism and density are all increased within “no take” MPAs compared to outside, or before the MPA was created. Also, the biomass of species in ”no take” MPAs from a range of different global locations are reported to have at least doubled compared to non-reserved areas (Palumbi 2003). These benefits have been reported from MPAs in both the northern and southern hemisphere (Babcock et al. 1999). While it is unclear how representative these samples from the literature are of the global experience with MPAs, it appears that reserves will in most circumstances provide these benefits, subject to various details of design and evaluation.

Table 2. Mean ratios of each biological measure (value inside the reserve divided by the value outside of the reserve, or before the creation of the protected area), for each functional group and for all trophic groups together. (from Halpern 2003)
Values are presented as the mean (calculated from the log-transformed data, then back transformed), plus or minus the standard error (calculated from the non-transformed data).
Invertebrate biomass and organism size and herbivore organism size all have 6 or fewer cases.
O = overall, C = carnivores, H = herbivores, P/I = planktivores/invertebrate eaters, and I = invertebrates.
P-values for two-tailed Student's t-tests, testing if the mean values are equal to zero, are as follows: *** = p < 0.001; ** = p < 0.025; * = p < 0.05. For invertebrate biomass, p = 0.053

	Density	Biomass	Organism size	Diversity (species richness)
overall	1.91 ± .28 ***	2.92 ± .92 ***	1.31 ± .07 ***	1.23 ± .07 ***
carnivores	2.21 ± 5.63 *	3.12 ± 1.23 **	1.31 ± .10 ***	2.40 ± .43 ***
planktivores/ invertebrate eaters	1.85 ± .56 ***	2.38 ± 2.19 **	1.23 ± .13 ***	1.35 ± .37 ***

herbivores	2.39 ± 2.67 **	3.33 ± 4.82 **	1.52 ± .36 **	1.39 ± .27 ***
invertebrates	2.04 ± 6.15 *	0.25 ± 2.23	0.80 ± .17 ***	1.08 ± .22 **

The various forms of spillover and larval export, and the basic assumptions and qualifiers and a simple conceptual model of how a protected area may be able to provide enhancement of a fishery are discussed in detail by Ward et al. 2001, and summarised below in Figure 2.



Immediate
Short-term
Medium-term
Long-term
Cessation of all fishing activity 1
Fishing damage stopped 12
Habitat condition improves 13
Spawning habitat condition improves 14
Biodiversity increases
Ecological function enhanced
Communities stabilise
Habitat complexity increases
Tourism boosted
Education and research opportunities provided 16
Settlement and recruitment enhanced 15
Fishing mortality eliminated 2
Individuals live longer 3
Mortality rates are lower 4
Mean age and size increase 5
Biomass & spawning biomass increase 7
Number and density increase 6
Population Abundance
'Natural' age/size structure re-established 17
Fishing selection reduced 18
Reduced loss of genetic information 19
Population Structure
Spawning activity and efficiency increases 9
Reproductive output increases 10
Protected Area
Spillover 8
Larval Export 11
Stability Enhancement 20
Fishing Grounds

Figure 2 (after Ward et al. 2001)

Conceptual model showing the pathways by which the establishment of a ”no take” reserve could lead to environmental enhancement of the area and potentially to enhancement of a fishery outside the reserve through the processes of spillover, larval export and stability enhancement. The large upper box represents a “no take” area, and the lower box represents the fished areas outside the reserve. Each text box within the reserve box represents an event, state or effect within the hypothesised cause-effect pathways; numbers are referenced in the text of Ward et al. 2001. The size of arrows roughly indicates the hypothesised importance of that pathway to the potential for fisheries enhancement. Very roughly, the time frame within which these events/states/processes might be expected to occur, following area protection, increases from ‘Immediate’ on the left to ‘Long-term’ on the right.

Text boxes 5-7 are grouped together to indicate that they are the processes involved in increases in population abundance, the most obvious manifestation of the process of reserve improvement.

Text boxes 17-19 are grouped because they are the processes responsible for the long-term changes to reserve populations, which along with the short-term abundance changes, are responsible for the improvements in population stability and resilience.

The very large arrows in the background indicate poorly defined pathways. Improvements to population structure have been hypothesised to feedback to improve population abundance, but the mechanisms have not been clearly identified.

5.5 Economic Benefits of MPAs in Fisheries

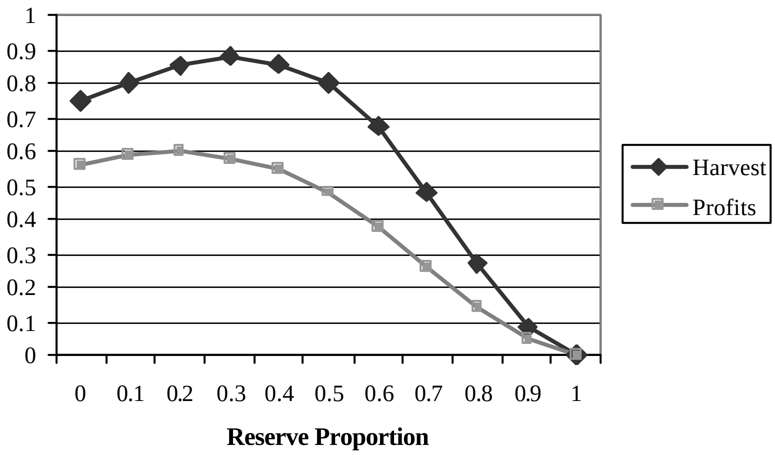
The possible economic benefits that MPAs, and particularly no-take reserves, may bring to a fishery have been widely discussed and various types of economic benefits have been modelled with different levels of realism. Simplistic models of fishery situations that range from complete open access to highly efficient and effective limited entry fisheries indicate that there are a number of situations where MPAs could bring significant benefits to a fishery, subject to the specific design of the MPA and the fishery management situation. Equally, however, there are several circumstances where the economic benefit of introducing MPAs to a fishery, if the benefits are narrowly interpreted (such as in profit from the existing fleet), can be negative. Factors that influence the level of benefit flowing to a fishery include:

- improvements in habitat within reserves
- the lower fishery management costs that MPA implementation could provide
- suitable strategies to deal with displaced effort
- accounting for the non-consumptive economic value of fish abundance and size

- patch size and migration of fish between patches

(Arnason 2001, Sanchirico & Wilen 2001, Sumaila 2000).

Depending on how these specific matters are considered within the MPA design process, an MPA may have a positive or negative economic benefit in a fishery. In simple bioeconomic models of the effect of introducing an MPA into an existing fishery, where the MPA causes a substantial increase in overall biomass of the target species (in the protected and fished areas), the MPA can provide a substantial improvement of efficiency in a fishery that is already optimally managed (Arnason 2001). However, in a fully open access fishery, the economic benefits of MPAs may not be as evident. The scenario in an optimally managed fishery, where an MPA increases biomass substantially, has been modelled as shown below.

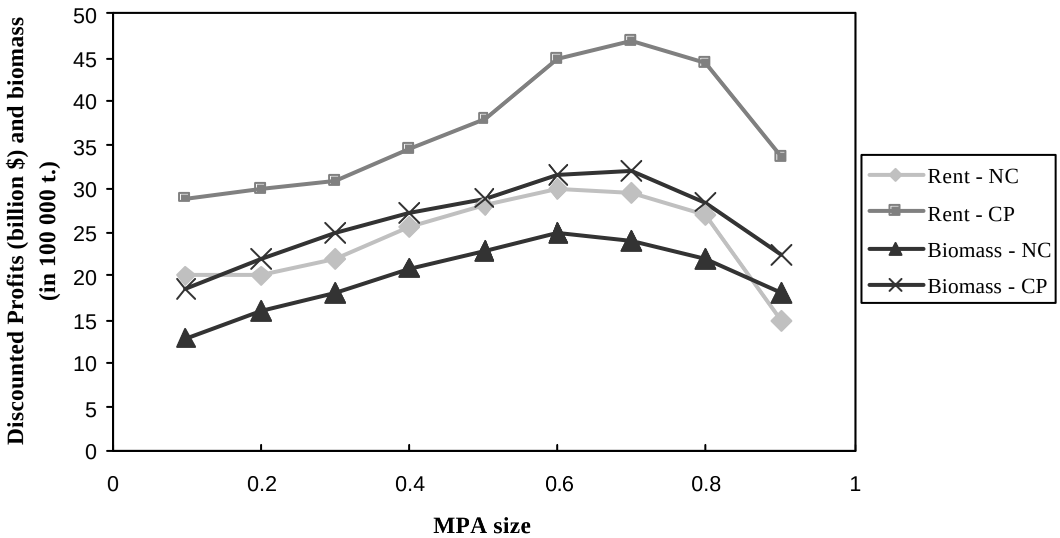


(reproduced from Arnason 2001)

These simple bioeconomic models do not take account of the costs of management of the fishery in the scenario where MPAs are introduced, nor the costs of management of the MPAs themselves. Depending on how the costs of these matters are determined and allocated, the net effect on a fishery may also be positive or negative (Arnason 2001, Armstrong & Reithe 2001). Similarly, these simple models take no account of the spatial heterogeneity in the fishery or the ecological systems, the likely economic values of the MPAs for other purposes (such as tourism, conservation etc), the possible increase in licence or entry fees to the fishery that flows from improved economic and ecological stability, or the likely direct assistance that MPAs may provide as insurance against stock collapse. Overall, the economic benefits appear to highly fishery-dependent, and difficult to predict without empirical experience of MPAs within the fishery concerned.

Arnason (2001) summarises the situation of introducing MPAs into a well-managed fishery in the following terms: “The imposition of marine reserves in an efficiently managed fishery may or may not be a good idea. Under some circumstances, marine reserves of a positive size may increase economic benefits in such a fishery. In other circumstances they may not.”

Models designed to examine economic benefits using realistic data from specific fisheries also show that, given certain set of assumptions, the introduction of MPAs can be of substantial benefit. Based on a model using data simulating the North-east Atlantic Cod fishery, Sumaila (2001) suggests that MPAs can protect the discounted economic rent from the fishery in the face of a major recruitment failure within the fished area, and if the fishers have a high discount rate. The total standing biomass increases with increasing MPA size but only up to a point. The study also shows that the economically optimal size of MPA for cod varies between 50 – 70% of the total area depending on: (i) the exchange rate of fish between the protected and unprotected areas of the habitat; (ii) whether fishers behalf cooperatively or non-cooperatively; and (iii) the severity of the recruitment failure in the fishery.



The economic benefits to the fishery, in the form of total economic rent, for the modelled fishery where there is both cooperative (CP) and non-cooperative (NC) behaviour of fishers in the fishery (reproduced from Sumaila 2001).

Beyond the direct economic benefits to fisheries, one important variable recognised as having a major potential influence on the economic benefits of MPAs is the benefits that may be external to the fishery, or only weakly connected. Such externalities introduce additional complexities that as yet have not been able to be introduced into economic models of MPAs in fisheries. These benefits are nonetheless well recognised by stakeholders, and can be important decision factors in MPA designs for fisheries purposes.

6. Protected Area Systems

Most protected areas already in use in fisheries management have been put in place to provide for protection of habitat considered to be critical to specific life stages of an exploited species. Or they may be used to protect areas where some part of the population may be exceptionally vulnerable to fishing in a way or at a time when this would have a major impact on the stock. While this is usually done to protect a fishery from its own activities, in some cases protected areas are declared to control the activities of other fisheries or other sectors that may be detrimental to an important fishery.

MPAs created for fisheries purposes may be designed to control effort and/or catch, to allow for uncertainty and retain breeding populations, to protect habitat and species that are important, whether directly or indirectly, to the fishery, and to limit effects of specific gear types. Throughout the world there are many design variations determining how these objectives are achieved. No single approach necessarily has global applicability as there is such extensive variability in the types, scale and knowledge of fisheries, local custom and management arrangements, and the available resources for management.

In their simplest form, the fisheries habitat reserve, all forms of fishing may be permitted within a designated area, sometimes subject to specific input or output controls for individual fisheries, but the habitat is protected from destruction or disturbance. This form of MPA is most useful in estuarine and near urban habitats where there are intense developmental pressures for landfill of tidal marshes and mangrove forests, for sand or limestone extraction, and for trained river entrances, sewage outfalls, utility corridors and causeways across tidal wetlands.

Another common form of MPA created for fisheries purposes involves establishing a spatial closure within which all forms of fishing for a particular species or for all species are either prohibited for a particular time of year, for a number of years until stock recovery takes places, or restricted to a specific gear type considered to be low impact.

A variant of this concept is for a specific gear type, such as an otter or beam trawl or a specific type of dredge, to be prohibited within a specified area. Such closures may apply at a critical season (seasonal closure) when breeding or spawning occurs, or throughout the year, either indefinitely (permanent closure), or for a number of years until stock recovery has taken place (sometimes called a replenishment area). Some gear closures are put in place specifically to protect habitats that may be important for other fisheries or for regional biodiversity conservation purposes. In these types of closures other forms of fishing are allowed to continue within the closure area.

In “no take” MPAs all forms of fishing are prohibited. While non-extractive research, recreational diving and tourism may be permitted, these should be constrained so as not to diminish the capacity of the habitats and ecosystems to sustain fisheries and provide for biodiversity conservation.

Within large multiple-use MPAs, many or all of the spatial management measures described above could be used in different zones within the MPA to provide comprehensive benefits to recreational and commercial fisheries. However, only a small number of types of spatial closures normally would be used in order to avoid having a management regime that is too varied and complex for users to understand and comply with.

6.1 Fisheries Examples

This section contains a brief summary of some specific examples of Marine Protected Areas that have been designed to provide benefit to fisheries. Some involve closure of areas to multiple fisheries across large areas of coastline, while the others are closures to specific gear or fishery types.

6.1.1 MPAs for Habitat Protection from Other Sectors

In recognition of the crucial role that specific inshore habitats play in various life stages of commercial species, the state of Queensland (Australia) has enacted Fisheries legislation that permits the declaration of Fish Habitat Areas (FHA). The objectives of FHAs are to protect the integrity, structure and fish habitat values of all aquatic habitats within the boundary of the declared area, and the protected habitats may include shallow-water banks and channels, seagrass, mudflats, and mangrove habitats. These protected areas are primarily established to prevent habitat degradation and do not prohibit fishing within their boundaries. FHA are considered crucial in the management of Queensland's coastal fisheries and help protect the regional viability of the fish, mollusc and crustacean stocks by supporting adjacent and offshore fishing grounds through primary production inputs, protection of nursery areas and feeding grounds, and protection of spawning locations. There are currently 75 declared FHAs distributed along the Queensland coast covering an area of over 740 000 hectares of fish habitats (Sheppard, in press).

The Queensland FHAs range from large areas in regions of low population density (such as Maaroom FHA in Great Sandy Strait, Fraser Island—23000 ha) to smaller areas in regions of high population development pressures. The FHAs are mostly focused on important intertidal and shallow water inshore habitats. As one example, the Temple Bay FHA on the eastern side of Cape York (Figure 3) covers about 4300 ha of intertidal shoreline and delta that comprises extensive mangrove (*Rhizophora* and *Ceriops*) forests, and is an important habitat for commercial prawns and fish, and for hawkesbill turtles. The uncommon mangrove *Dolichandrone spathacea* also occurs in this FHA (Beumer et al. 1997).

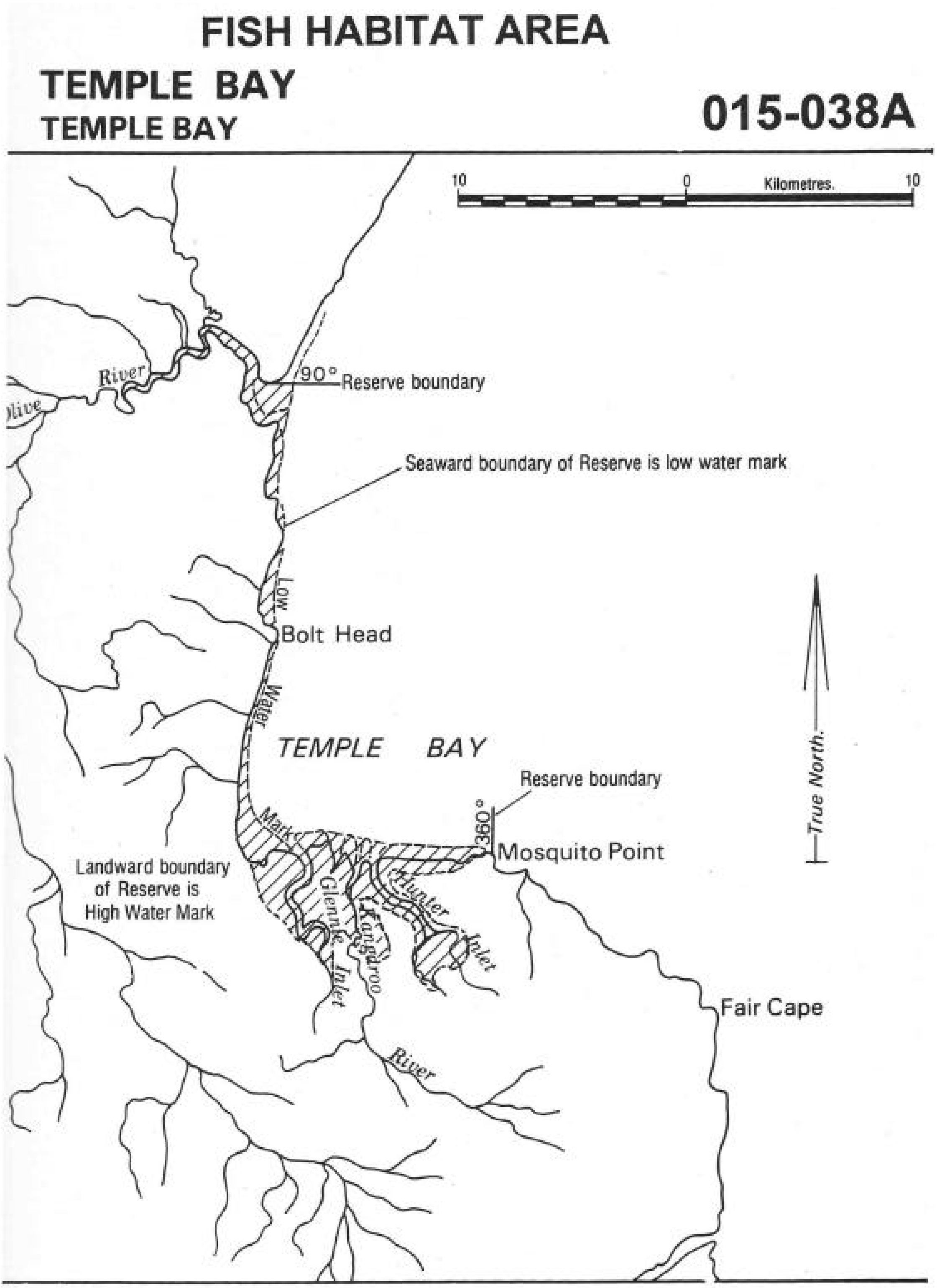


Figure 3
Temple Bay Fish Habitat Reserve, Cape York, Queensland (from Beumer et al. 1997).

6.1.2 Habitat Protection from Specific Gear Types

The state of Western Australia has spatial closures over large areas of the inshore tropical continental shelf to protect fisheries habitats from the destructive impacts of bottom trawling. The main closed area (Figure 4) covers an area of inshore shallow waters along more than 1000 km of tropical WA coastline, and is designed to protect pearl oyster habitats from the effects of trawling. There are also many other smaller tropical areas of WA permanently closed to trawling, including areas of Exmouth Gulf, Ningaloo Reef and Shark Bay. These closures have been implemented primarily to protect sensitive inshore habitats from trawling impacts, and to avoid detrimental flow-on effects in the dependent fisheries or aquaculture operations.

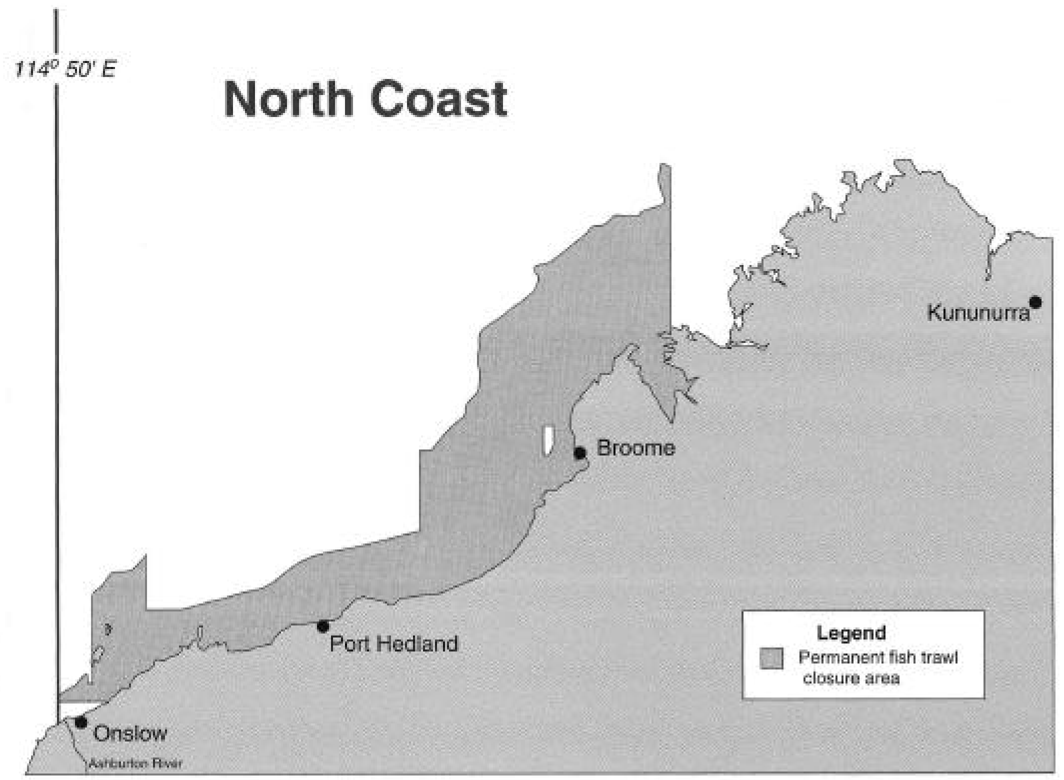


Figure 4
The North Coast bioregion of Western Australia, showing inshore areas of permanent closure to fish trawling (from WA State of the Fisheries Report 2001/2002).

In another example, the Great Australian Bight Marine Park off southern Australia excludes demersal trawling to protect the seabed and associated biodiversity. The Marine Park was designed in close consultation with fishing sectors, although the primary aim was to conserve biodiversity and specific mammal species. The benthic protection zone (Figure 5) is a strip 20 nautical miles wide extending from the inshore 3 nautical mile State Waters zone to the 200 nautical mile boundary of Australia's EEZ. By excluding demersal trawling from the benthic protection zone the Park contributes a significant offset to the destructive impacts of demersal trawling along the continental shelf break in the Great Australian Bight.

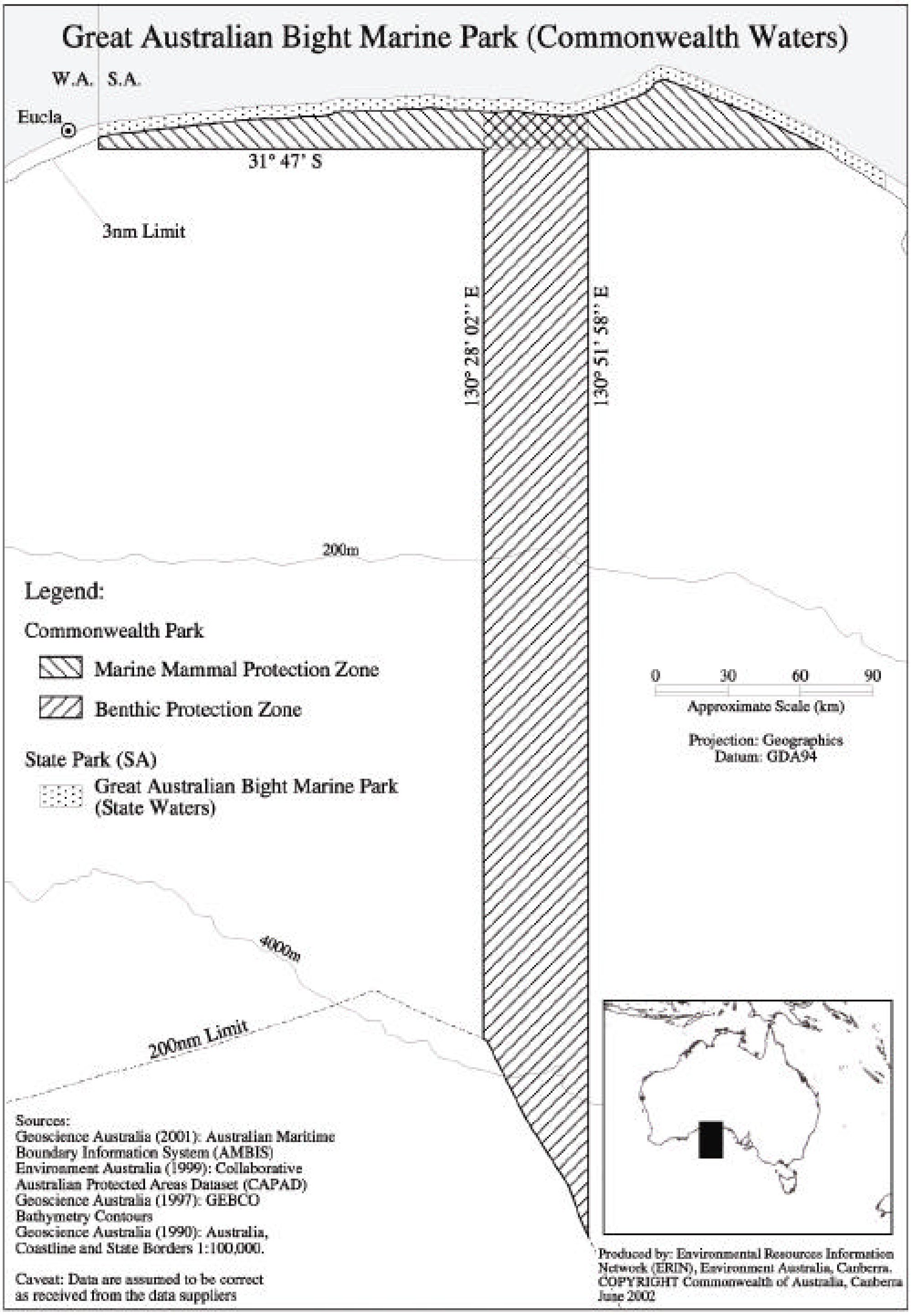


Figure 5. The Great Australian Bight Marine Park (Commonwealth Waters) (source: Department of the Environment and Heritage)

6.1.3 Community Based Single Species Replenishment Closure

Fisheries closures are sometimes of short duration and focused on a single species. In northern Cape York, Queensland, the apparent rapid decline in an Australian indigenous subsistence fishery for black jewfish resulted in indigenous fishers participating in a stock assessment with researchers. This study revealed that sexually-mature fish comprised less than one percent of the subsistence harvests of earlier years. As the fishery was previously based on adult fish, the traditional landowner groups of the area (the Anggamuthi, Atambaya, Gudang and Yadhaykenu Aboriginal people) self-imposed a two-year ban on the harvest of black jewfish.

After extensive consultation, this initiative developed into a regional agreement, with comprehensive support across all communities of northern Cape York and the adjacent Torres Strait Islands. The area of closure incorporates the inshore waters north of Crab Island (on the west coast) and Albany Island (on the east coast). The principal aim of this community-developed management response is to allow local black jewfish stocks to reach a mature size so that prospects for replenishment are improved (Phelan, in press).

6.1.4 Large-Scale Commercial Tropical Reef Fishery

The Reef Line Fishery (RLF) in Australia's Great Barrier Reef (GBR) region comprises three main sectors: commercial, recreational and charter. The commercial sector is based on the use of single baited hooks on heavy line on rod and reel or hand reel, operated from small dories (4 to 7 m length) associated with primary vessels (8 to 19 m length). The fishery operates across the full length of the GBR, with a focus in the area between Rockhampton and Cairns, an area of about 90,000 km^2. More than 125 species are caught in the commercial fishery, but the main targeted species in the fishery are the common coral trout (*Plectropomus leopardus*) and the red throat emperor (*Lethrinus miniatus*). Coral trout, which comprise 3 main species and 4 other species, make up 35 to 55% of the total catch in the commercial fishery. The commercial sector of the fishery catches about 3,000 to 4,000 tonnes per annum of all species, although this has fluctuated substantially in the last 10 years, particularly in response to the improved prices available for live-marketed fish.

The Great Barrier Reef has a series of about 80 areas that are closed to fishing, covering about 16,000 km^2, about 4.5% of the total area of the Great Barrier Reef Marine Park. These closed areas represent about 16% by number and perimeter of the GBR reefs, and about 23% of the area of reefs. These closed areas (zoned as Marine National Park, Scientific Research or Preservation were established to protect samples of the reef systems of the GBR. In the remaining areas of the GBR many reefs and the area between reefs are open to fishing, and the region supports valuable wild capture fisheries for many species of fish, crustaceans and other invertebrates.

A detailed study of the RLF fishery (Mapstone et al. in press) shows that, in areas that have been closed to fishing for more than 10 years, the common coral trout and the red throat emperor are more abundant, larger and older than in adjacent areas that have always been open to fishing. The magnitude of the 'reserve effect' varies across the GBR, from almost none to several-fold depending on the variable assessed and the area. This spatial variability in effectiveness of the reserves for these species is ascribed (Mapstone et al. in press) to the effect of fishing activities in the adjacent areas that are open for fishing. This indicates that although the closed areas provide support for the fishery in some areas (through the maintenance of populations of reproductively mature individuals), the extent of this support depends on design (location, boundaries etc) of the reserves and the fisheries management measures in adjacent (fished) areas.

The closed areas in the GBR were established originally to protect the biodiversity of the reefs of the GBR system, and not designed specifically to protect these fish species. While the closed areas were not specifically designed to benefit the RLF, it is clear that they do provide important benefits for the fishery.

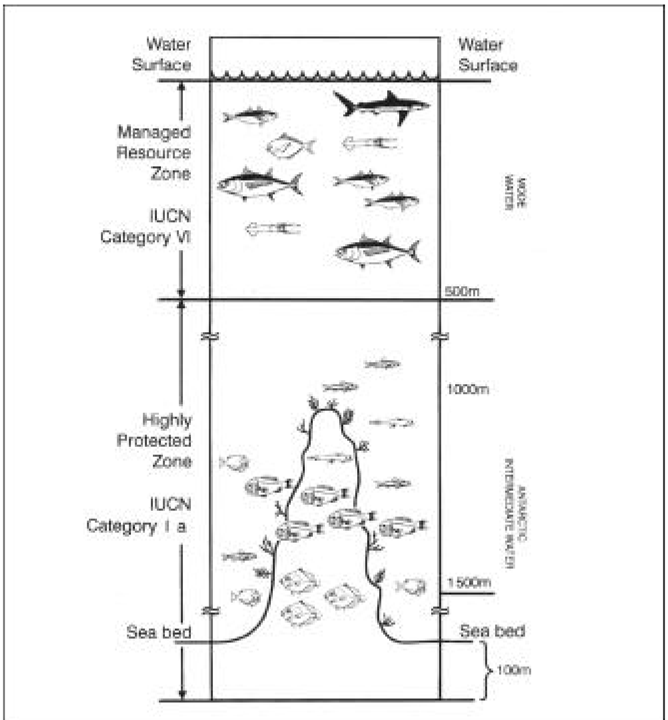
Mapstone et al. (in press) developed a detailed model of the RLF that includes spatial resolution of about 4,000 reefs and similar habitats, and a range of life history parameters for coral trout. Using three likely scenarios for fishing effort in the future, and a simple strategy for further reef closures, the model predicts that the most effective way to preserve spawning biomass (the main stock sustainability objective for the RLF) is to increase area closures as a mechanism for reducing effort in the fishery. Under the specific management regime applied in the RLF, where the minimum permitted size ensures that many fish will be able to spawn at least once before capture, effort in the fishery is considered by Mapstone et al. (in press) to be the factor most likely to drive changes to specific stock management objectives (such as the maintenance of spawning biomass and harvestable biomass). If an area closure strategy sought to maximise benefits to the fishery, such as taking account of spatial relationships between open and closed areas in the light of recruitment and fishery characteristics, in a scenario of increased area closures, the reserve effect may be able to provide an enhanced support for the fishery. Implementation of closed areas designed to improve accessibility of the harvestable biomass to fishers and optimise recruitment to the fishery, while still meeting nature conservation objectives, may be able to discount some of the negative impacts on fishers that a fishery-wide reduction in effort using other measures would create.

6.2. Multiple-use Protected Areas

Various types of area protection can be used to assist a fishery, ranging from the protection of habitat alone through to a full "no take" MPA. In some circumstances, MPAs will have a mixture of types of uses permitted, such as recreational fishing and tourism, but will exclude some other forms of exploitation, such as mining or trawling. The blend of various activities would normally be established in a zoning scheme, so that the various objectives that the protected area is expected to achieve can each be attained in a balanced manner (see Figure 5). Such zones may be organised to provide a core area that is "no take" where only non-extractive research and monitoring is permitted, perhaps surrounded by larger areas where some low-impact uses are permitted, such as small-scale fishing or tourism. In these zoned systems, it is feasible to expect that a range of different objectives can be attained by a protected area (or network) and that these may be spread across a broad range of users and interests.

This approach has been widely adopted in Australia, with a range of types of protection applied for fisheries, tourism and conservation purposes. In Australia's south-east, for example, a series of deepwater seamounts and their overlying waters have been protected for conservation purposes in the Tasmanian Seamounts Marine Reserve, which covers 370 km^2. The seamounts emerge from the continental slope and rise to within about 700 to 1200 m of the ocean surface. The waters shallower than 500m depth in these protected areas are open for fishing with specific gear types, but the waters below 500m and the seabed and seamounts themselves are protected as a "no take" reserves where no fishing or other resource extraction (oil, minerals etc) is permitted (Figure 6).

The effectiveness of the different forms of protected area for fisheries purposes depends on their design, and particularly where they are located and what forms of fishing or other uses are permitted, as well as the adequacy of surveillance and enforcement programs.



Cross section of water column and sea-bed showing management zoning and the IUCN category for each zone.

Figure 6. Zonation in the Tasmanian Seamounts Marine Reserve.
(source: Tasmanian Seamounts Marine Reserve Management Plan; Environment Australia, Canberra. 2002)

7 Designing Reserves that Work

Designing reserves that work relies on having objectives that are meaningful and achievable. Establishing objectives that are agreed and are integrated across the interests of the various stakeholders requires a systematic approach to MPA design, and a supportive policy and operational framework within which the design and implementation activities should operate.

7.1 A Supporting Framework

For dual or multiple-objective MPAs to be effective in the long term, they need to be designed and implemented within a policy framework that provides support for the objectives of the MPA, and discourages perverse incentives that might act to prevent an MPA from achieving its objectives. Because of the broad base of ocean users, the high value of marine species and ocean ecosystems, and the lack of existing integration mechanisms, planners of dual/multiple-objective MPAs need to ensure that the design and implementation processes are fully consultative. This is best conducted in the context of an integrated bioregional approach to management of ocean ecosystems and uses. Some jurisdictions will require new institutional structures to ensure this is carried out efficiently and effectively, and some countries may also require new legislation to empower an integrated approach to management of ocean resources.

A number of countries have recognised this problem (including Canada, USA and Australia), and have initiated various forms of oceans management policy designed to encourage the more efficient and effective management of the ocean resources. These are broadly based on the concept of integrated management systems, and use ecosystem-based management (Ward et al. 2002) and more integrated bioregional planning and management systems that explicitly recognise and implement MPAs for the conservation of regional biodiversity (and see Section 2 above).

The successful implementation of dual/multiple-objective MPAs depends on the long term commitment and respect of the various ocean users, and the extent to which their objectives can be individually and collectively achieved through the MPA program. This can only be based on a detailed involvement of a broad spectrum of the stakeholders and users in design and implementation of MPAs.

An integrated monitoring and assessment program that evaluates and reports on how the MPAs have influenced both conservation and usage in the bioregion is also crucial for ensuring an ongoing commitment of users and stakeholders. This program should be designed as part of an integrated approach to assessment of the condition of ocean ecosystems, and in particular, how resource uses relate to conservation trends. Such assessment programs may be best implemented through interagency agreements and cooperation, with public accountability and reporting. In this way the responsibility for monitoring and assessment of MPAs in the context of sustainable use of resources is shared across a range of ocean users and responsibilities, and forms an important part of the process of integrated support for dual/multiple-objective MPAs.

7.2 Design issues

The first, and potentially most critical challenge to be faced when designing a marine reserve is to define the objectives that the reserve is expected to achieve. While this may seem obvious enough, conceptualising objectives at a level that can by implemented is difficult when the objectives are either expressed at a high level (strategic objectives), are complex, or are of only a short term nature. When objectives are simple, as may be the case for a fishery where a specific habitat type is recognised as a critical nursery area for the target species, then operational implementation of an effective reserve is perhaps easiest. This is the case, for example, for fisheries habitat reserves where the objective is to prevent physical alienation of the habitat by foreshore reclamation works, or by mining or other destructive activity. But when objectives for the MPA are more complex, or only expressed at a strategic level (such as ‘protection of biodiversity’) then implementation requires a much more complex design and consequent set of activities. And when there are multiple sets of objectives, such as joint fisheries and conservation objectives, the design issues usually become more complex because the different objectives may be specified in different ways, be expressed at different levels of ecological organisation, and at different scales of spatial resolution. However, the converse—artificially constraining objectives so that a reserve will be easy to design and implement—is probably the most ill-advised approach of all, because a reserve designed on this basis will fail to meet the real objectives and ultimately lose the support of managers, fishers and stakeholders alike, and probably substantially fail to protect biodiversity or support the fishery at any level.

Where objectives involve design of a reserve to protect populations of a particular species or type of habitat/or ecosystem, key issues usually involve biophysical matters such as prevailing current flow, larval dispersal, the size of the area required to ensure the population is self-sustaining and is adequately linked to sources of recruits or food, and other ecological factors such as protection of major spawning aggregations or nursery areas. There have been many attempts to establish a generic set of MPA design criteria (eg Nilson 1998, Salm & Price 1995), but from a conservation perspective the most comprehensive set of criteria have been developed by IUCN (Kelleher 1999). From a fisheries perspective, criteria can be more explicitly linked to the benefits described in section 5 above, and to the objectives for the exploited species.

Matters usually considered when designing reserves can be classified into three main groups:

- biophysical requirements, conditions and constraints
- existing uses and obligations
- practical management constraints, including the interaction with external pressures.

The biophysical design issues are the most often discussed in the scientific literature, but practical experience in MPAs shows that there are many other, often related, types of issues involving socio-economic matters, traditions and customs of local communities, and stakeholder engagement (Day et al. in press).

Biophysical issues, for both conservation and fisheries objectives in MPAs, often revolve around questions of existing conditions, oceanographic patterns, mobility of the main species of interest in their adult, juvenile and larval stages, and the minimum MPA size. The spacing and location of MPAs to ensure ongoing linkages between habitat patches is usually considered crucial, to maintain metapopulations and their genetic diversity (Gerber et al. 2002, Lockwood et al. 2002, Acosta 2002). However, it is prohibitive to measure such parameters for all marine species, so that reserve designs normally need to be based on predicted (or assumed) distribution characteristics of the main species. Typically, there is only very limited empirical biophysical data available to reserve planners, including information on exploited species.

In order to account for the vast uncertainty in knowledge about all the species found in marine habitats and ecosystems that are expected to be protected by an MPA, reserve planners almost invariably resort to various surrogates in order to ensure that biological factors are incorporated as far as practical in the design of MPAs. These surrogates may be higher-order taxonomic resolution of marine species or assemblages, or may by biophysical habitats, or even substrate types (Ward et al. 1999, Day et al. in press). While surrogates may not provide complete or adequate representation of marine populations, MPAs usually attempt to encompass a representative range of different habitat types to capture biodiversity that has not been specifically modelled or used in the reserve design process.

Because of the high levels of uncertainty about inclusion of species, populations and even habitat types of unknown distribution, reserve designs therefore often include different zones of managed uses. This is to try to ensure that where only small no-take core areas can be secured, the surrounding uses are not highly destructive, so that at least many of the normal biophysical processes may still be maintained in the surrounding areas in a way that allows the no-take core to continue to provide for effective conservation of the biodiversity it contains. This concept of spatial dependency and interaction of zones is captured in the IUCN classification system in the graded series of protection within the different classes of MPA.

Reserve planners are thus able to use the concept of nesting of levels of protection to ensure that MPAs have a broad base of acceptance to the users and stakeholders, while still providing for effective conservation outcomes delivered through the combination of zones where the primary objectives range from sustainable use (VI) to no-take reserves (IA/IB & II) (see Table 1). In this sense, the less-protective zones (such as VI) can be used as a buffer area to reduce the risk to the biodiversity in the core areas of the reserve (which could be classified as IA or IB).

However, in addition to providing a buffer for the higher-protection zones by ensuring, for example, limited degradation of habitats and ocean productivity, MPAs managed to achieve category VI sustainable usage objectives will contain substantial biodiversity in their own right. These category VI areas may be a vital component of conservation of larger, more mobile species that cannot be properly sampled and protected fully within smaller no-take core areas.

While it is clear that the success of a system of reserves depends heavily on its design, there have been few documented examples of reserve designs that have failed to support a fishery. There are many examples of MPAs that do not appear to achieve their main objectives (eg Nickerson-Tietze 2000), but few have been assessed in any detail to determine why they fail to achieve useful outcomes. Many instances of failure can be directly related to a failure of management controls, such as failure of controls on access, or on use of destructive fishing gear.

In South Africa, reserves created to support the rock lobster fishery are considered to have failed, because the densities of lobsters inside the reserves are similar to those outside the reserves, and the proportion of egg production of the reserves is proportional to their area of the overall coast, indicating no enhancement of the lobster population by the MPAs (Mayfield et al. 2002). This situation is considered to result from a lack of controls on fishing in the MPAs, but also because the reserves were arbitrarily situated in locations that do not have good habitat for rock lobsters.

In constructing a nested system of reserves with different permitted levels of use, MPA planners will always have to be aware of the role of dominant uses of surrounding areas, the likely long term consequences of uses and activities in adjacent areas that may not be protected or well managed, and any important ecological and physical gradients.

Apart from biophysical factors, reserve designs need also to take account of the placement of boundaries and the shape of reserves, to ensure that day-to-day management can be conducted in an efficient and effective manner. Clear and easily distinguished boundaries, even with the modern availability of GPS systems, are still very important to ensure that users can be fully aware of the boundaries and zones of an MPA.

Ideally, in commercial fisheries that operate within or adjacent to MPAs, each vessel should be required to carry a vessel monitoring system that transmits the position of the vessel to a monitoring agency, and a log book that records fishing sites and catches. In many cases this can be less expensive than the alternative, which is to provide for a fishery-independent system of compliance monitoring to ensure that violations of the rules of the MPA are reported. Fishery independent compliance systems may include sufficient aerial surveillance and/or boating patrols to provide a credible deterrent. In a high value fishery like Australia's Northern Prawn Fishery, the industry may decide to ensure compliance by funding and utilizing both approaches.

In coastal and island areas, it may be most effective for MPAs to be established adjacent to terrestrial protected areas, such as existing nature reserves, national parks, or community controlled areas. Such MPAs will benefit from a more natural set of interactions with the terrestrial systems (including land runoff etc) as well as potentially sharing management controls and systems with the terrestrial area, such as monitoring of visitors for compliance with reserve rules.

The need for monitoring and performance assessment is normally well understood by natural resource managers. In the case of MPAs, this is especially important because of the natural tendency to ignore the underwater and out-of-sight aspects of a reserve system where observations may be more difficult and expensive than land-based monitoring. Creation of MPAs is often achieved by reducing access of specific user groups, some of whom may have a traditional and long-held access to these areas for fishing, tourism, recreation etc. For both commercial fisheries and for these other stakeholders it is therefore always important to ensure that reserve performance is adequately monitored and reported in a manner that is accessible and understandable by each stakeholder group. The crucial role of this monitoring and reporting is to ensure that stakeholders are fully informed about the effectiveness of the MPA, and to build stakeholder support for the ongoing maintenance and management of facilities and staff to manage the reserve. Where stakeholders are not fully engaged and supportive of MPA design and rules, experience shows that the MPA will not be effective, because in time the stakeholders will be able to either violate the reserve with no fear of reprisal, or work to alter the boundaries or rules in their favour and reduce the value of the reserve (see for example Russ & Alcala 1996).

The establishment of a feasible and effective performance assessment and reporting system is also important for ensuring that the objectives for which the MPA was established are being met, including both fisheries benefits and biodiversity conservation (and see Section 7.3 below), and so that any improvements needed to the reserve, such as change in the boundaries to ensure the objectives can be fully achieved, can be properly justified to all stakeholders. For commercial activities, this becomes especially important so that the role of the MPA in any economic benefits can be made explicit.

Size of an MPA is often discussed as a key criterion. And this sometimes is expressed as a proportion of available area, and used to establish targets, such as 20% of the total area for a specific type of MPA. However, size in itself is not a useful criterion for selection of areas to include in an MPA. The size of an MPA must be large enough to ensure that the objectives for the MPA can be achieved, accounting for uncertainty in the design process and the varying utility of any surrogates used to determine boundaries and location of the MPA, and any zones. A more critical criterion is (typically) the adequacy of the size of the MPA to achieve the objectives. In this context adequacy refers to the area, location and boundary arrangement, in the context of the specific complement of habitats and ecosystems, that will efficiently and effectively achieve the biological objectives of the MPA.

This means that while size is an important parameter that may be used to describe an MPA, and is a useful comparative descriptor for policy purposes, it has little biological meaning in isolation from a competent reserve design, and so cannot be used as a *criterion* for choosing areas to include within an MPA. Likewise, proportions based on areal comparisons (such as 20% of a region) have little value as criteria for *selection* of MPAs, although they are useful as comparative measures across different jurisdictions and bioregions if they compare the proportions in each habitat of the bioregions/jurisdictions.

As an example, if an MPA is to provide both support for a fishery and protect key habitat types of a bioregion, it would need to ensure that it secured a sufficiently large number of samples of the habitats in question, across the full range of the bioregion (to account for variability within the bioregion), and that it secured these samples at places where they would provide most benefit for any fisheries dependant on species that used these habitats. To ensure that both sets of criteria (adequate range of habitats and support for the fisheries) were applied effectively, the number of individual areas required to meet both criteria may be greater than are needed to meet only each criterion individually. This may be considered useful to ensure that uncertainty in the process is appropriately conservative.

While the final selection of areas to be included in an MPA to meet complex objectives may comprise a broader set of areas than to meet each single objective, the broader set of areas will have a range of other values that also contribute to conservation outcomes in the region. The definition of how many such areas, or the size each one should be, or its location, is best ascertained using expert judgement, models of population and habitat distribution, and taking account of any known biophysical gradients within the region. Implementing such an approach usually requires decision-support, because of the large number of parameters being considered and the possible range of spatial outcomes, and procedures to assist in this are discussed in section 7.4 below.

7.3 Dealing with displaced effort

In many situations where MPAs are to be declared there will be already existing uses that will, or may, be either removed or displaced to other locations outside the MPA. In some fisheries, this is a particularly difficult problem because fish stocks are managed using quotas which are issued to fishing groups or individuals without spatial constraints that control where they can catch their quota. Most quota-managed fisheries are also supported by a range of input controls (such as gear type), but few also have spatial controls. In any case, fishers may well argue that the declaration of an MPA over ground they have customarily fished is a removal of an existing (or traditional) right, and hence may be subject to compensation in financial terms or access to other fishing grounds, species or fisheries which they cannot currently access. This raises the important issue of the displacement of fishing effort into the non-MPA areas, and how this might interact with the MPA itself, the objectives of the MPA, or affected fisheries.

Establishment of an MPA that reduces access to existing fishing grounds does not necessarily mean that catch from the fishery overall will decline in proportion to the area of the MPA. The magnitude of the impact will depend on the nature of the fishery management system that is in place, the life history of the exploited species, and perhaps most importantly, the effectiveness of the MPA in providing additional recruits etc for the fishery.

In fisheries that are over-exploited, the shift of additional effort into non-reserved areas may be more than the stock can withstand, and possibly cause a fishery to crash.

However, studies of such fisheries indicate that the converse is the usual outcome of creating a no-take reserve—highly over-exploited fisheries benefit by protecting key portions of the stock from fishing, enabling them to then provide spillover and/or larval export that ultimately provides the basis for recovery of the fishery. This is a well-established phenomenon, and has been observed in both tropical and temperate fisheries of various scales; indeed closing a fishery to all (or most) fishing is the usual response by fishery managers to signals of stock collapse in a fishery (Gell & Roberts 2003, Fisher & Frank 2002).

In a well-managed fishery, the effects on a target stock of the increase in Effort Per Unit Area (EPUA) that would follow from creation of a no-take reserve may be well within the capacity of the stock to withstand, at least for a period of time. For both situations (over-exploited and well-managed) the impact of the displaced effort will depend largely on three factors:

- effectiveness of the fishery management system that is in place, and its ability to manage the displaced effort;
- life history of the exploited species (benthic phases, pelagic phases, spawning behaviour, migratory, etc);
- effectiveness of the reserve design in providing recruits or adults into the fishery.

In addition to the impact of increased EPUA on fished stocks, the potential for ecosystem impacts needs to be assessed. It will be crucial to ensure that declaration of an MPA does not result in increased EPUA that involves use of different gear types, or more intensive fishing in places previously only lightly fished. This would have increased consequences for biodiversity in the non-reserved areas. Such consequences may include increases in bycatch, additional fishing into deeper unprotected waters, or use of more destructive gear types. Models developed to assess the effects of MPA declaration on fisheries suggest that the way in which displaced effort is managed is crucial to capturing the benefits of the MPA (Haddon & Buxton 2002, Apostolaki et al. 2002, Baum et al. 2003). For modelled over-exploited stocks and fully-exploited stocks of both sedentary and mobile species (including spiny lobsters and Mediterranean hake), there are yield and productivity benefits that can be secured from introduction of MPAs, but this is only if displaced effort and fishery selectivity are correctly adjusted and managed in the non-reserved areas.

In some circumstances, introduction of an MPA (or a network of MPAs) may be the main tool that is available for recovering a fishery to an acceptable level of productivity. However, in those fisheries that are perhaps fully-exploited, or where there is a marginal over-exploitation, the creation of MPAs may precipitate the removal of some fishing capacity from the fishery, in order, say, to deal with displaced effort. While this is not necessarily a consequence of all MPA declarations, it is usually a risk perceived by fishers, and is a matter that generates significant initial opposition to MPA proposals.

For MPAs to be properly implemented to provide support for fisheries, it is clear that all the management controls need to be reviewed and assessed, and it may be necessary to completely revise the management basis of the fishery, such as adding spatial management to a quota management system. While this is necessary to ensure that the MPAs are effective and efficient in their delivery of fisheries benefits, it may also be linked to other forms of restructuring in the fishery, such as economic reforms and rationalisation of competition policy.

In developing MPA proposals that are intended to provide support for fisheries, it is always important to ensure that any socio-economic impacts of the MPAs are not considered in isolation from the other aspects of the fishery that may be related. These include the current levels of exploitation, and the potential for other direct and indirect benefits in the local region, such as employment in leisure and tourism ventures.

7.4 Assessing Performance

An efficient assessment of the performance of an MPA relies on the clear expression of the objectives and targets that are intended to be achieved through the MPA (Syms and Carr 2001). Determining what objectives and targets are feasible and achievable for an MPA should be based on a consideration of the full scope of potential benefits that an MPA may bring to a fishery. A recent review of the role that "no-take" MPAs can play in fisheries management identified 58 potential benefits that such a protected area may be able to provide to a fishery (Ward et al. 2001). Of these, the main benefits that a protected area may be able to deliver to a fishery are:

- enhanced conservation of fishing-affected species or habitats either in or outside the reserve
- stock enhancement within the reserve
- stock enhancement overall or outside the reserve
- improved overall fishery yields
- improved socio-economic outcomes for local communities

These various benefits may apply widely across different fisheries, ecosystems and target species. Not all fisheries could achieve all 58 potential benefits, and the realisation of any benefit depends on the species concerned, the state of the fishery for that species, and perhaps most critically on the effectiveness of the reserve design process and the protected area management and compliance processes. In particular, how the design criteria are developed to match the objectives and implemented to select areas, and how the area is managed to achieve the objectives will determine whether any protected area will make a positive and supportive contribution to fishery management.

The main potential fishery benefits from "no take" MPAs, summarised in Table 2, also can be used as measures of performance for any form of protected area because "no take" MPAs approach the highest possible form of protection, and so are likely to create the greatest spread of benefit types.

Protected areas that are designed to have levels of protection less stringent than the no-take reserve also can offer many of these same benefits, although the benefits may be reduced to an extent determined by the nature and extent of protection afforded the area. Evidence suggests that fishing has a measurable effect on both the target species and the ecologically linked (non-fished) species in local ecosystems (Edgar & Barret 1999) although this effect does not appear to be consistently observed across all locations and studies (Ley et al. 2002, Mapstone et al. in press). The design of such studies, including the parameters chosen to be measured, the rigour of the experimental design, the time frame, as well as the intensity of fishing being excluded, and the target species of the fishery, all may contribute to the mixed findings of such studies.

For example, where a fishery is heavily overfished it is not surprising that introduction of a protected area, especially a "no-take" MPA, would result in a substantive impact on the target species within the MPA (Apostolaki et al. 2002, Gerber et al. 2003), albeit for some species recovery may take a number of years (Roberts et al. 2002). Conversely, in a well managed fishery, introduction of a "no take" MPA may have less of an effect on the target species, take much longer to be expressed, and be more difficult to measure. The problems here relating to experimental design are well known from other areas of science, including ecology. Exclusion experiments are a well-used experimental tool, and impact assessment, where designs such as Before/After Control/Impact, are used to establish reliable inferences about impacts and establish more robust cause-effect relationships (Osenberg & Schmitt 1996).

The life history characteristics of species also are thought to be important in determining how species react to area protection. For species that are long-lived, wide-ranging and perhaps of low fecundity, and may have populations controlled by density-dependant processes, creation of an MPA may not result in much measurable benefit, at least in the short term. And conversely, area protection for such species may be counter-productive, if it falsely assumes population protection and allows exploitation in other areas that are unprotected or less protected (Mayfield et al. 2002). Similarly, as discussed above, the redistribution of fishing effort and any changes in selectivity in the fishery (such as targeting of smaller fish) that may result from area protection are important factors that will influence the success of a reserve (Apostolaki et al. 2002).

Table 2 Potential fisheries benefits from "no take" MPAs (adapted from Ward et al. 2001)

Biological Benefits Within a protected area	exploited species	enhanced abundance and/or density
		enhanced mean age and/or size
		natural sex ratio maintained
		natural age-size-sex population structure maintained
		reproductive output (eggs / larvae) enhanced
		spawning stock protected
	biodiversity	areas of undisturbed habitat established/maintained
		habitat complexity enhanced
		species diversity enhanced
		community complexity (e.g. trophic complexity) enhanced
		important local ecosystem processes maintained
Outside the protected area	for exploited stocks	fishery yields enhanced
		abundance and/or density enhanced
		reserve provides recruitment source through export of eggs and/or larvae
		reserve provides source of post-larval stages through emigration
		abundance maintained
		age-size-sex structure improved
		reserve provides insurance against management failures (i.e. stock collapse)
		intraspecific genetic diversity protected
	biodiversity	habitat complexity, species diversity and/or community complexity enhanced
		important regional ecosystem processes maintained
	other exploited species	fishery yields maintained
Management Benefits		enforcement simplified, rules clear
		ease of public understanding and acceptance of management
		provides sites and facilitates multi-disciplinary scientific study of natural ecosystem structure, function and dynamics
		defends against non-sustainable development options for the reserve site, by excluding incompatible activities
		contributes to integrated ecosystem based management of marine ecosystems
		data collection requirements reduced
		contributes to improved estimates of focal

		species population parameters (such as natural mortality, population structure)
		provides sites and facilitates education and training opportunities
Economic Benefits	Local and regional effects	local economies augmented
		economic opportunities enhanced and diversified
		opportunities for employment in local industries enhanced
		opportunities for low-impact traditional or subsistence fishing or gathering of natural marine resources enhanced
Social Benefits		social and cultural well-being of local communities maintained
		contributes to satisfying public expectations of government programs to protect the marine environment

7.5 Optimisation approaches

Designing an MPA to meet both conservation and fishery objectives will often result in some objectives being in spatial conflict. For example, it may be that some estuaries that have a high conservation value are also the only places where a particular fishery operates. Resolving these potentially conflicting objectives can be difficult, and if the bioregion is large, then a range of MPA options may be feasible, and a decision-support system may be required in order to objectively evaluate the full range of possible options. Nonetheless, as discussed above, designing the MPA may also involve exploring trade-offs within the fishery, such as providing access to other fishing grounds, perhaps other species or other areas, in the context of a review of the relevant fisheries management controls and resource allocations.

Various approaches are available to establish the ecological and fishery values of particular areas that are being considered for MPA dedication. These range from purely expert judgement through to complete data-driven decision-support systems that produce a single best outcome based on the objectives and the available data. Simple decision systems based on expert judgement, while cheap and able to capture a wide range of data and knowledge, are subjective, and will always be open to accusations of bias. Whereas, data-driven decision support systems are expensive, may take considerable time to implement, and are also subject to difficulties with model assumptions and inadequate data. Resolving such matters in the face of competing objectives and uses is complex, and may be best resolved using a systematic cost-effective blend of both approaches.

Often the fishers themselves will hold the best information, in the form of accumulated experience, including experience of anomalous events and knowledge of fishing grounds, of which scientists and managers may be unaware. Their data may include actual fishing locations and routes, depth information, and substrate information, which together with catch statistics, can be very important information for an MPA planner.

Designing an effective MPA will almost always require the full involvement of stakeholders, and this also means that there is an increasing requirement for transparency and accountability in the way in which MPAs are selected, and a requirement for a highly systematic approach. A systematic approach to reserve design is considered by Margules & Pressey (2000) to consist of 6 basic steps:

1. compile data
2. identify conservation goals
3. review existing areas
4. select additional areas
5. implement conservation actions
6. maintain the required values.

In any specific MPA design problem, the systematic procedures for reserve design may take a number of different forms, each customised to the individual requirements of the design problem being addressed. While many planners use algorithms in Step 4 (above) of the systematic approach, the broad context in which these algorithms are applied are often very different. The context, approach, or framework to the design problem appears to be as important in determining the MPA outcome as the specific choice of algorithm. This extends also to the nature of datasets used as inputs to such decision support systems.

'*Conservation planning is riddled with uncertainty'* (Margules & Pressey 2000). Every step of a systematic MPA design process, each dataset, each assumption, and each procedure is uncertain (Syms and Carr 2001); and worse, for some the extent of this uncertainty cannot be calculated. Uncertainty can be generated from each of:

- Unclear communication (lack of a common understanding of concepts and issues)
- Description errors (errors in data measurements)
- Variability (heterogeneity in an environmental quantity)
- Data gaps (measurements not made)
- Uncertainty about a quantity's true value (wide distribution of data points)
- Model structure (the underlying conceptual model is incomplete or incorrectly structured)
- Model form (the type of model being used as the basis for planning is not appropriate).

Each MPA design problem is different, but all need to acknowledge that outcomes are uncertain because they are generated by processes that are uncertain. Responding to such uncertainty is crucial, and ignoring it in MPA design is a serious mistake. This does not invalidate reserve selection outcomes, but indicates that procedures seeking to identify reserves must be implemented in ways that recognise and respond to such uncertainty. Even then, the outcomes are likely to be uncertain, so where the biodiversity stakes are high (if the biodiversity is of high national or international value and the risk of loss is real) the existence and persistence of biodiversity in a chosen set of MPAs needs to be confirmed in a program of validation. This is best achieved through an ongoing program of research and monitoring designed to test outcomes against assumptions and expectations, and to verify that management arrangements are working to ensure the persistence of the nominated biodiversity.

The main contemporary approaches to MPA design employ computer-based optimisation approaches that use conservation (biodiversity) features and values as the basis for choosing areas for protection, and the principle of 'complementarity' to choose MPA candidate areas (Ball & Possingham 2000; Sala et al. 2002). The conservation features/values may be biodiversity expressed at a number of levels of spatial, temporal and taxonomic resolution, and may include high profile species, biodiversity parameters such as endemism, assemblages of flora or fauna, and physical habitats and environments. The values may include specific fishery values, such as places of high value as spawning aggregations, as well as places of high value as fishing grounds.

The process of choosing areas based on their complementarity involves identifying an area, or group or areas, then adding to this the next area that contains a feature not currently contained in the set, and repeating this until the target for each feature has been met within the chosen set. Increasingly, stakeholders are being consulted and involved in identifying such features and their targets, and in identifying existing and potentially conflicting uses. All modern approaches are based on identifying the smallest (or an optimum) set of areas in the face of the specific biodiversity targets and constraints, known broadly as the 'minimum set'. The three main types of algorithms used to systematically identify reserves are simple iterative selection algorithms (heuristics), iterative simulated annealing, and linear integer programming.

Heuristics are fast and flexible, easily programmed, and provide good solutions that can be close to the optimal, although the degree of sub-optimality cannot be determined without considerable additional research, and they are unable to efficiently include simultaneously many conservation features and constraints. Simulated annealing may include many conservation features and constraints, and can provide excellent solutions that are close to optimal, but is slower and more complex to implement. Integer programming provides the optimal solution to any simple reserve design problem, but cannot efficiently include a large range of conservation features and constraints, and at present is not sufficiently well developed for application to major MPA design problems.

Heuristic algorithms have a strong and well documented history of application to reserve design problems, and are the basis for terrestrial reserve design research over the past decade or more. Simulated annealing has been more limited in its use until recently, but has now been used in several marine and terrestrial reserve design applications, and is the currently most feasible decision-support option for MPA design (Ward 2003).

These decision-support procedures require empirical data, and expert knowledge, in order to be able to assess options and generate MPA outcomes that are near-optimal in terms of meeting the various objectives. Such empirical data, for the purposes of MPA design, may be captured in cost-effective rapid assessment programs that are designed to provide a broad-area overview, for example with selective spatial contrasts. These rapid assessment surveys may, to restrain costs and time required, also adopt a specific level of taxonomic resolution for fauna and flora, and may include detailed sampling of specific habitat types in order to provide an overview of spatial distribution of identified habitats of interest. In addition, such surveys may focus on providing specific distributional data designed to validate modelled distributions derived from pre-existing data on species or habitats of interest, and to check assumptions about biota-habitat relationships implicit in the use of surrogates. Overall, while MPA designs will always rely on quality empirical data, it is not necessary for MPAs to depend on new empirical data to enable reserve designs to be undertaken. Existing data may be adequate, including biophysical surrogate data, modelled and validated with carefully designed and selected programs, using specific rapid survey approaches set within an focused approach to data capture (Ward et al. 1998, Vanderklift & Ward 2000). In this way, with relatively cost-effective data capture programs and a carefully focused framework, modern optimisation techniques can be used to help resolve the complex problems of design of dual and multi-objective MPAs.

7.6 Involving Stakeholders

The role of stakeholders in the design process for an MPA is crucial. Stakeholders should normally be involved from the commencement of the process, including the designing of the process, and then contributing at each step in the process, including the ongoing monitoring and evaluation. The objective of stakeholder involvement with the design process is to secure an effective engagement and involvement with the decisions about all aspects of the MPA. Stakeholders will bring independent views to the design and optimisation process, and the MPA design should attempt as far as possible to respond to the various issues that they may raise without prejudicing the MPA objectives.

In preparing to consult with stakeholders, MPA planners should recognise the following 8 basic tenets of stakeholder consultation (after Langstaff 2003):

- every MPA is likely to be different, and have different issue emphasis;
- the earlier in the process stakeholders and their concerns are identified, the better;
- the consultation process should be designed and communicated as early as possible;
- requests for stakeholder input must be active, not passive;
- the stakeholder consultation process should be designed and carried out in a way that is culturally and technically appropriate;
- a meaningful stakeholder consultation takes time;
- a neutral environment is needed for honest and open exchange of information, perspectives and concerns;
- the consultation process must be open, responsive and transparent.

A particularly important role for stakeholders is in assisting to determine the environmental values where the fishery operates, and how the fishery objectives will interact with the conservation objectives for the region taking account of the MPA.

The process of designing an MPA needs to be as inclusive as possible of stakeholders, including indigenous people, with effective procedures for seeking their input. A strategy for defining any problems through identifying and working through the perspectives of different stakeholders will help to clarify collective objectives for the MPA, and in particular how they interact with the fishery management objectives and fishing activities. An effective dispute resolution mechanism needs to be available for issues that cannot be resolved through a consensus-based consultation process.

The stakeholders can assist the MPA design and management process by contributing to a strategic vision for fishery management, helping to explore where the fishery could be placed in five or ten years time, and considering the trade-offs that the wider community may be prepared to make to achieve that end. If it is properly designed and implemented, the stakeholder consultation process should:

- enable an integrated approach to fishery and MPA management;
- take regional ecosystem effects of the fishery into account, and
- provide for mitigation of the impacts of the fishery on habitats, non-target fish species, and associated and dependent species such as marine mammals and sea birds, through a coordination of the MPA and other fishery measures.

Fishing need not be detrimental to the ecosystem if the fishery management objectives and strategies contain measures to restrain effects to acceptable, defined and agreed levels, including through the use of no-take reserves and other forms of MPA (Ward et al 2002). Securing stakeholder participation in the MPA design and management process is a central feature of ecosystem-based management, and provides a transparent basis for sustainable fishery management.

The design and strategies for an MPA should be readily available to the public and contain clear and explicit rules and procedures (that may include how to deal with traditional and customary practices). The planning and management arrangements need to be easily understood by all stakeholders, and apply to all sectors harvesting the resource including the recreational sector, and to all users of the region. Periodic external review of the MPA management system and its performance by independent peer reviewers is essential to maintain technical rigour. Compliance and enforcement strategies and monitoring and performance evaluation procedures also need to be outlined, made accessible, and communicated clearly to all users and stakeholders.

Vital to the success of the MPA are clear strategies and procedures for management and for ongoing monitoring and regular performance evaluation involving stakeholders. This includes a stakeholder involvement in reviews of the fishery harvest strategy, MPA and fishery short and long-term sustainability objectives, operational criteria and performance measures for those objectives, and procedures for monitoring the performance measures.

Conceptual models linking the fishery resource to the biodiversity and ecosystems where the fishery operates should be clear and transparent to stakeholders. This should include all aspects of the harvest strategy demonstrating how the management process works in accord with the management plan and what the role of the MPA is in terms of both conservation objectives for the region and fishery objectives.

8. Realising Benefits of Marine Protected Areas in Sustainable Fisheries

Within fisheries, the nature and extent of potential benefits of MPAs will depend on the nature and effectiveness of a fishery management regime. Reserves, in the form of closed areas, have been used in fisheries management for many years as a tool in support of specific fisheries. For example, as described above, it has long been recognised that many shallow water coastal habitats provide important areas of critical habitat for many species in coastal fisheries, as feeding, breeding, spawning grounds or migration routes. In many countries such habitats are specifically protected through fisheries legislation to support stocks or identified species. And, in stock management, fishery closures in both time and space have long been used to ensure that a specific stock of a commercially valuable species is protected from exploitation at a sensitive time, such as during breeding or spawning. Such protected areas are used to ensure that fishing effort is controlled so that, for example, the stock can be maintained above a minimum threshold to ensure replenishment and ongoing sustainable catches. Such reserves have therefore a well recognised and important role to play in stock management in many modern fisheries.

However, reserves also can assist with a large range of other management issues that are now being recognised as key issues in the management of modern sustainable fisheries. In the fisheries that have well-developed management systems, delivering such benefits requires:

- stock assessment models that are spatially explicit at the scale of the protected area;
- good information on the biology and ecology of the exploited species;
- criteria for ecosystems and biodiversity that can be incorporated into fisheries management systems;
- a careful evaluation of the costs and the benefits related to specific protected areas, and
- a willingness for institutions to work together.

Existing fisheries reserves have value for the conservation of biodiversity, even those reserves that may be temporary closures, or that have only a specific fishery protection objective, such as protection of a spawning area. These benefits include conservation of the target stock, but also conservation support for at least some of the other species, habitats, geological formations, culturally important sites and artefacts etc that also may occupy the fishery reserve. These may include species that the target species exploits for food or shelter, but equally may include species that are only indirectly and distantly ecologically linked to the target species, and those that are not linked at all.

However, fully understanding benefits from reserves for fisheries will require development of models that accept spatial resolution of exploited populations, admit multiple sites (the reserves) for spawning, recruitment, etc, and are structured to accept population sub-components that are not available for fishing. These models may use the reserve populations as a standing supply of breeding stock, or reproductive propagules for the fishery, or use in other ways the refuge population components of the exploited species.

Using strategic and systematic reserve design procedures, fishery reserves may also be able to achieve important levels of conservation for regionally distributed species. Such “no-take” MPAs, jointly designed for fisheries and conservation offer the opportunity for specific fisheries to simultaneously achieve benefits for both their business and regional biodiversity conservation. Dedicating a series of MPAs may assist a fishery to provide a form of compensation to the ecosystems for the impacts of fishing by ensuring that any such reserves adequately sample and protect habitats and ecosystems that elsewhere are being fished (Carter et al. in press). In this sense, the reserves may be able to be used to trade-off for some of the ecological effects of fishing in other nearby areas.

These benefits will assist a fishery to meet its sustainability objectives, and provide a context for triple bottom line accounting and reporting. Triple bottom line reporting (TBL) is the emerging benchmark for resource sector businesses to give effect to the intent of sustainable development within their core business operations (Whittaker 1999). Given the minimal ongoing maintenance requirements, their high value for conservation, and possible benefits for fisheries themselves, “no-take” MPAs appear to offer fisheries a cost-effective opportunity for quickly reducing levels of environmental concern about excessive fishing effort, and associated environmental and stock damage, as well as the overall cost of fishery management in the medium term and beyond (Ward in press).

It seems that area protection can work efficiently and effectively for marine capture fisheries, but in extending the concept to also deliver conservation outcomes, the important problem is agreeing on what the area protection should be trying to achieve.

9. Catalysing Action

9.1 The Policy Imperatives

It is clear from the extensive history of using protected areas for fishery purposes that protected areas have been designed to be effective at providing support for specific fish stocks. The pressure on global fisheries is mounting through increases in demand for fish, increasing pressure on economic efficiency in fisheries, and a parallel reduction in refuges for fish. Fisheries management systems are also experiencing serious difficulties dealing with uncertainties introduced through environmental variability, and with the impacts of fisheries on non-target organisms and habitats.

At the same time, ocean (particularly coastal) ecosystems have come under greatly increasing pressure from other forms of exploitation, from habitat alienation and destruction, introduced marine pests, and pollution. In response to the increasing suite of pressures on ecosystems, conservation managers have called for more extensive declarations of protected areas to achieve conservation goals for the world’s marine biodiversity. While it is acknowledged that reserves established for fisheries purposes will also make some contribution to the broader conservation of biodiversity in a region, these fisheries-based reserves are not often included within national or global tallies of protected areas because their goals are narrow, in the sense of biodiversity conservation, and they are not always highly secure, because their protection status may be downgraded easily to allow an increased level of exploitation, or they may be easily ignored because of a lack of local monitoring, enforcement and compliance with reserve rules. Also, fisheries reserves are established under different legislation and government portfolios from those of strictly conservation-based reserves, and this dictates separate reporting mechanisms.

There is a high level of urgency, reflected in the outcomes from the WSSD, to establish fisheries that respect ecosystem sustainability and are conservatively managed to avoid adverse impacts both on stock and on ocean ecosystems. This is also reflected in a number of countries in various forms of integrated oceans management policy and legislation. The various global and national policy initiatives all intend to underpin fisheries that are more sustainable, have fewer impacts on non-target species and habitats, and can be considered to be more ecologically sustainable. Protected areas have been widely identified as a key tool that can be used to satisfy a number of the objectives for improving the sustainability of global fisheries and simultaneously achieving biodiversity conservation objectives.

For fisheries, protected areas can be designed to improve the stability in a fishery. They may help by creating a more efficient and effective way of buffering the fishery against the effects of a range of uncertainties, and protect key parts of stocks and important habitats as has been the long-held tradition in many fisheries. And they may help to trade-off for the impacts of the fishery on a range of non-target species and habitats.

Given the imperatives for fisheries to become more sustainable, including more robust to these uncertainties, and the global concern about the ongoing degradation of ocean habitats and species, the primary challenge facing both fisheries and conservation managers is how to work together to establish protected areas that will serve both sets of functions. This will become an imperative in order to ensure that protected areas are designed and implemented in an efficient and effective manner, optimising the use of ocean space, maximising the benefits gained for both fishing and conservation (the ‘double payoff’) and minimising the costs of design, implementation and ongoing management of such protected areas. An integrated management “partnership approach” also allows agencies to build a stronger case to government for special funding for dealing with ecosystem impacts, and to approach other agencies who have legislation to deal with impacts that are beyond the powers of conservation or fisheries agencies.

For fisheries agencies, the key benefit of this partnership approach is that conservation agencies legislation may contain greater powers for controlling impacts on fisheries by other sectors. In addition, it holds the promise of effectively dealing with ecosystem impact issues that in many countries threaten to close down fisheries if they are left unresolved, either because public opinion will force closures or because the ecosystem damage will impact directly on the profitability of the fisheries.

For conservation agencies the key benefit of the partnership approach is that the traditional opposition to marine protected areas (fisheries agencies and fishing industry organisations) clearly benefit from the declaration of marine protected areas and hence become the strongest advocates, rather than opponents.

MPAs can be designed to achieve an optimal set of outcomes for both fisheries and conservation, but so far there are few documented examples. Together with the traditional animosity between conservation agencies and resource management agencies, this is preventing progress on establishing protected areas that deliver the double payoff.

9.2 The Gaps

As with other complex areas where predictions are difficult because of the nature and extent of interactions between human institutions, the dynamics of ecosystems, a lack of basic knowledge, and the generation of wealth, we consider that the most effective and efficient approach to learning how to implement MPAs will be derived from a process of gradual implementation and learning from our mistakes. This means that existing world-wide models of MPA design, implementation and assessment need to be continuously reviewed and improved through explicit analysis of successes and failures—the kernel of adaptive improvements.

The complexities of design and implementation of MPAs to achieve both fishery and regional conservation benefits, and our lack of global experience with MPA design and management, mean that a simple path cannot be easily charted for the future. In terms of recognising and responding to the global MPA policy imperatives handed down from WSSD, there are three key gaps that can be recognised at the regional, national and sub-national jurisdiction level:

- there are as yet no fully documented examples of success to provide effective leadership and guidance;
- there is a lack of an operational framework that would underpin the development and implementation of dual or multi-objective MPAs;
- the benefits for fisheries, whilst likely and achievable, are poorly demonstrated.

9.2.1 Few models of success

The limited world-wide experience with MPAs, the institutional constraints on reporting of failures, and the lack of comprehensive monitoring and assessment systems have prevented MPA planners from conceptualising and describing models of success. Considerable effort has been dedicated to community-based conservation areas, and models of stakeholder participation and community management have emerged that have more general applicability. Models suggest that there are MPA designs that can provide good benefits for both conservation and fisheries (see for example Hastings & Botsford 2003). But there have been few documented examples of MPAs dedicated explicitly for both fishery and bioregional conservation objectives (although there are some in the planning stages), and no case study assessments that determine what aspects of these MPAs were successful, and what failed.

This lack of successful established practice has prevented a broader uptake of the concept by both fisheries and conservation agencies, and natural institutional inertia has compounded this to prevent a more integrated approach to MPA design and implementation. We consider that this lack of successful established practice is substantially impeding the uptake of the concept of dual or multi-objective MPAs on a global basis. Demonstrations embodied in real case studies, building on the wealth of theories and empirical argument, will convince many more fishers that they stand to benefit from carefully designed and managed MPAs.

9.2.2 Lack of integrated assessment and management framework

A major blockage to effective design and implementation of dual or multi-objective MPAs is the sectoralisation of governance and wealth generation in the oceans. The plethora of government agencies with direct controlling interest in ocean uses in all countries with an EEZ is direct testament to this problem. This promotes division, institutional competition, and a lack of integration of objectives in relation to uses of the ocean. While most countries have legislation or procedures that are intended to avoid this fractured approach to management, the imperative for integration is usually downweighted to be one of coordination alone (i.e. we wont tread on your toes if you don't tread on ours), and this typically leaves natural resource agencies and conservation agencies to contend with the unmanaged consequences of activities that have impacts on ocean ecosystems. And worse, in some countries and jurisdictions, the coordination is ineffective, and fisheries agencies and conservation agencies are in open conflict about levels of use and protection of the oceans required under their respective mandates. Some countries (including Australia) have recognised this problem and are in the process of implementing oceans management arrangements to avoid the unwanted consequences of a failure to recognise the values of biodiversity caused by the incremental degradation from a range of uncoordinated ocean users with differing objectives.

For the specific problem of dual-objective MPAs, the major lack of integration is between fisheries and conservation agencies, and this applies at regional, national and sub-national jurisdictional levels. We consider that this matter is probably the most crucial issue to be addressed in order to enable effective implementation of MPAs world-wide. There are several approaches that could be used to resolve this problem, but the most promising is a system of coordination that involves government, industry and community partnerships to address the problems of managing ocean ecosystems, and specifically including dual-objective MPAs in the context of sustainable use of ocean ecosystems.

9.2.3 Few demonstrated fishery benefits

Fisheries world-wide are sceptical of the benefits that a system of dual-objective MPAs can provide. They argue, with some substance, that despite the theoretical potential benefits of MPAs, the benefits have yet to be demonstrated in all but a handful of tropical reef fisheries that have been grossly over-exploited and generally lack any recognisable form of fishery management system beyond complete open access to all resources. Others argue that a well-managed fishery can be most efficiently and effectively managed by classical fisheries single-species stock management models and approaches, and that reserves serve only to reduce efficiency of management and yield to a well-managed fishery. This lack of a wide range of demonstrated successes of no-take reserves in fisheries management is a considerable obstacle that is hindering the implementation of dual-objective MPAs.

The reticence of fisheries to accept the concept uncritically is completely understandable, given their obvious economic dependence and the (usual) focus on the single objective of stock management and yield. A major part of the argument is that while benefits to conservation can be well demonstrated, benefits to fisheries are not. In this context, the potential benefits are broad, covering issues such as employment in the fishery, investment returns, and vitality of local communities, as well as the more familiar biological benefits such as catch from the fishery, and fishery operational costs such as greater distance to fishing grounds. We consider that the lack of demonstrated benefits to a modern well-managed fishery that uses no-take reserves within its management system is severely hampering broader acceptance of the dual-objective MPA concept.

9.3 High Priority Corrective Actions

9.3.1 Develop An End Game Vision

A key factor preventing adoption of protected areas as a broadly-based tool for oceans management is the lack of a vision for how such areas can be designed and implemented to achieve the dual objectives. The lack of this 'end game vision' seems to be a key constraint that is preventing a committed engagement from government agencies, the community or the private sector.

Those seeking to promote dual-objective MPAs will need to focus on working with all parties to ensure an equitable involvement in identifying protected areas that can potentially meet a broad set of jointly developed objectives, with identified costs and benefits. Various successful approaches have been identified, and optimisation software programs and processes are now available that can be used to facilitate this process. What now remains is the development of a successful vision for dual-objective MPAs at a range of jurisdictional levels that meets the users and stakeholders requirements. This should include different types of jurisdictions and clarify policy and implementation models that would operate effectively in a nested series of levels from regional to sub-national (fishery) levels.

9.3.2 Improve Institutional Arrangements

The failure of conservation and fisheries institutions to work together in an effective and efficient manner to address the issues of dual-objective MPAs is a crucial issue and must be resolved. There are several potential mechanisms that can be applied at a range of jurisdictional levels:

- establishment of regionally integrated management systems that recognise the role of various agencies and levels of government and community, but maintain a focus for management on ecosystem values
- as a component of regionally integrated management, establishment of partnership MPA programmes that are integrated between fisheries and conservation agencies, and are closely consultative with other levels of government
- establishment of an assessment system that reports against the broad base of benefits that can be delivered from marine protected areas, including fisheries, biodiversity, tourism, and others
- establishment of standards and targets for ocean ecosystems that would be met by all agencies and users of the oceans in each jurisdiction. This would need to be developed with the involvement of all stakeholders and ocean agencies in each country. In most countries such standards and targets would need to be empowered by specific legislation and new arrangements.

9.3.3 Document Success Stories

The limited nature of success stories should be resolved by establishment of a series of case studies that, world-wide, focus on specific fisheries and assist in implementing dual-objective MPAs, and reporting in detail on the success and failures of these initiatives. There are already anecdotal reports of various levels of success with dual-objective MPAs, and some limited analysis (eg Nickerson-Tietze 2000) but these are rarely fully assessed and reported in the open literature. The intention here is to identify existing and new MPA initiatives and document their successes and failures in the open literature so that a body of established practice can begin to be developed and ultimately provide leadership for MPA planners in both fisheries and conservation sectors.

9.3.4 Role of Fishery MPAs in Regional Conservation of Biodiversity

There has been considerable technical analysis (modelling and some empirical data) of the role that MPAs play in supporting fisheries, but the role MPAs created for fisheries purposes play in supporting biodiversity conservation has received very limited technical attention. This is important because, at present, fisheries closures are largely discounted from national and regional assessments of protected area conservation, yet obviously, they do make a contribution. While there is some knowledge of the contribution of fishery reserves to the exploited species, the exact nature of their broader contribution to biodiversity conservation is largely unknown. The contribution of fishery-designed MPAs to regional conservation objectives should be the subject of a range of empirical studies targeting specific fisheries that have a history of MPA implementation to determine what contribution the fishery closure policy has had on regional biodiversity conservation. In concert with this, it will also be important to improve national and international reporting systems to incorporate reserves established for fisheries purposes. The criteria for inclusion are whether the fisheries reserve can me et the definition of an MPA and whether it can be assigned an IUCN Protected Areas Management Category.

10. Sources/Citations

Acosta C. A. 2002. Spatially explicit dispersal dynamics and equilibrium population sizes in marine harvest refuges. *ICES Journal of Marine Science* **59**: 458–468.

Alder J. and Ward T. J. 2001. Australia's Oceans Policy — Sink or Swim? *Journal of Environment and Development* **10**, 266-289.

ANZECC 1999. ANZECC Task Force on Marine Protected Areas **Guidelines for Establishing the National Representative System of Marine Protected Areas**. In: Strategic Plan of Action for the National Representative System of Marine Protected Areas; A Guide for Action by Australian Governments. Environment Australia, Canberra July 1999

Apostolaki P., E. J Milner-Gulland., M. K. Mcallister & G. P. Kirkwood 2002 Modelling the effects of establishing a marine reserve for mobile fish species. *Canadian Journal of Fisheries and Aquatic Sciences* 59: 405-415.

Armstrong C. & S. Reithe 2001. Marine Reserves – will they accomplish more with management costs? A comment to Hannesson's (1998) paper. In: Economics of Marine Protected Areas. Ed U. R. Sumaila, UBC Fisheries Centre Research Reports 9 (8), 2001. Vancouver, Canada. p11-18.

Arnason R. 2001. Marine reserves: is there an economic justification?. In: Economics of Marine Protected Areas. Ed U. R. Sumaila, UBC Fisheries Centre Research Reports 9 (8), 2001. Vancouver, Canada. p19-31.

Ball I. & H. P. Possingham 2000. MarXan (V1.2) **Marine Reserve Design using Spatially Explicit Annealing. A Manual Prepared for The Great Barrier Reef Marine Park Authority**. March, 2000. 63pp

Baum J. K., R. A. Myers, D. G. Kehler, B. Worm, S. J. Harley & P. A. Doherty 2003 Collapse and conservation of shark populations in the Northwest Atlantic. *Science* **299**: 389-392.

Beumer J., L. Carseldine & B Zeller 1997. **Declared fish habitat areas in Queensland**. Department of Primary Industries, Brisbane, Qld. 178pp.

Bohm, C. 2002. Environmental challenges for the new Australian super fishery. *Waves* **9**(1): 3.

Carter, D, E.J. Hegerl, & N. Loneragan (in press).
The role of marine protected areas in the management of the Australian Northern Prawn Fishery. Paper presented to the World Congress on Aquatic Protected Areas 2002, Cairns, Qld.

Commonwealth of Australia 1999. Environment Protection and biodiversity Conservation Act 1999. No. 91, 1999, 534 pp.

Eagles, P.F.J., S.F. McCool & C.D. Haynes 2002. Sustainable Tourism in Protected Areas: Guidelines for Planning and Management. IUCN Gland, Switzerland and Cambridge, U.K. xv + 183 pp.

Edgar G. J. & N. S. Barrett 1999. Effects of the declaration of marine reserves on Tasmanian reef fishes, invertebrates and plants. *Journal of Experimental Marine Biology and Ecology* **242**: 107-144.

FAO 2002. **FAO Guidelines on the Ecosystem Approach to Fisheries (Final Draft).** FAO Rome 2002.

FAO Code of Conduct for Responsible Fisheries
<http://www.fao.org/fi/agreem/codecond/codecon.asp>

Fisher J. & K. Frank 2002. Changes in finfish community structure associated with an offshore fishery closed area on the Scotian Shelf. *Marine Ecology Progress Series.* **240**: 249–265.

Galal N., R. Ormond & O. Hassan. 2002. Effect of a network of no-take reserves in increasing exploited reef fish stocks and catch per unit effort at Nabq, South Sinai, Egypt. *Marine and Freshwater Research* **53**: 199-205.

Gell F. and C. Roberts 2003
The fishery effects of marine reserves and fishery closures. WWF US (in press)

Gerber L.R., P. M. Kareiva & J. Bascompte 2002. The influence of life history attributes and fishing pressure on the efficacy of marine reserves. *Biological Conservation* **106**: 11 –18.

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

Haddon M. & C. Buxton 2002. The effect of introducing MPAs on a commercial fishery - a rock lobster example. Paper presented to the World Congress on Aquatic Protected Areas 2002, Cairns, Qld.

Hall S. J. 1999 **The Effects of Fishing on Marine Ecosystems and Communities**. Blackwell Science, Oxford.

Halpern B. S. 2003. The impact of marine reserves: do reserves work and odes size matter? Ecological Applications, 13(1) Supplement, 2003, pp. S117–S137

Hastings A. & L. Botsford 2003. Comparing designs of marine reserves for fisheries and for biodiversity. *Ecological Applications* **13** Supplement: S65-S70.

Hutchings J. 2000 Collapse and recovery of marine fishes. *Nature* **406**: 882-885

Jakarta Mandate on Marine and Coastal Biodiversity <http://www.biodiv.org/programmes/areas/marine/background.asp>

Jennings S & Kaiser M. J. 1998 The effects of fishing on marine ecosystems. *Advances in Marine Biology* **34**: 201-352.

Kelleher G. 1999 Guidelines for Marine Protected Areas. World Commission on Protected Areas, IUCN, Gland. 107pp.

Kelly S., D. Scott, A.B. MacDiarmid, R.C. Babcock 2000. Spiny lobster, *Jasus edwardsii*, recovery in New Zealand marine reserves. *Biological Conservation* **92**: 359-369

Langstaff L. 2003. **Guidance for Certification Bodies on Stakeholder Consultation in MSC Fisheries Certification Assessments**. Unpublished report to the Marine Stewardship Council, London.

Ley J., I. A. Halliday, A. Tobin, R. N. Garrett & N. A. Gribble 2002. How do fishing closures influence fish biodiversity? A case study. Paper presented to the World Congress on Aquatic Protected Areas 2002, Cairns, Qld.

Lockwood D. R., A. Hastings & L. W. Botsford 2002. The effects of dispersal patterns on marine reserves: does the tail wag the dog? *Theoretical Population Biology* **61**: 297–309.

Mapstone, B.D., C.R. Davies, L.R. Little, A.E. Punt, A.D.M Smith, F. Pantus, D.C. Lou, A.J Williams, A. Jones, G.R. Russ & A.D. MacDonald (in press). The Effects of Line Fishing on the Great Barrier Reef and Evaluation of Alternative Potential Management Strategies. CRC Reef Research Centre, Townsville, Australia. 220pp.

Margules C. R. & R. L. Pressey 2000. Systematic conservation planning. *Nature* **405**: 243-253.

Mayfield S., L. Atkinson, G. Branch & A. Cockcroft 2002. Rock lobsters, reserves and redundancy. Paper presented to the World Congress on Aquatic Protected Areas 2002, Cairns, Qld.

Murawski S.A., Brown R, Lai H.L., Rago P.J., & Hendrickson L (2000). Large -scale closed areas as a fishery-management tool in temperate marine systems: the Georges Bank experience. *Bulletin of Marine Science* 66:775–798

Nilsson P. 1998. **Criteria for Selection of Marine Protected Areas**. Swedish Environmental Protection Agency, Sweden. 54pp.

Nickerson-Tietze D. 2000. Scientific characterization and monitoring: its application to integrated coastal management in Malaysia. *Ecological Applications* **10**: 386-396.

Osenberg C. W. & R. J Schmitt 1996. Detecting ecological impacts caused by human activities. In: **Detecting Ecological Impacts, Concepts and Applications in Coastal Habitats**, eds R. J Schmitt & C. W Osenberg, Academic Press, NY. Pp3-16.

Pauley D. V. Chrstensen, S. Guénette, T. Pitcher, R. Sumaila, C. Walters, R. Watson & D. Zeller 2002. Towards sustainability in world fisheries. *Nature* **418**: 689-695.

Palumbi S. 1999. The prodigal fish. *Nature* **402**: 733-735.

Pezzey J. C. V., C. M. Roberts & B. T. Urdal 2000. A simple bioeconomic model of a marine reserve. *Ecological Economics* **33**: 77–91.

Phillips B., Ward T, & Chaffee C. (eds) 2003. **Eco-labelling in Marine Fisheries**. Blackwell Science, Oxford.

Pitcher T. J. 2001. Fisheries managed to rebuild ecosystems? Reconstructing the past to salvage the future. *Ecological Applications* **11**: 601-617.

Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem 2001. In: Report of the Reykjavik Conference on Responsible Fisheries in the Marine Ecosystem. Reykjavik, Iceland, 1–4 October 2001. FAO Fisheries Reports - R658 <www.fao.org/fi>

Roberts C. P., J. Bohnsack, F. Gell, J. Hawkins &R. Goodridge 2001. Effects of marine reserves on adjacent fisheries. *Science* **294**: 1920-1923.

Russ G. & A. Alcala 1996. Marine reserves: rates and patterns of recovery and decline of large predatory fish. *Ecological Applications* **6**: 947-961.

Sala E, O. Aburto-Oropeza, G. Paredes, I. Parra, J. Barrera & P. Dayton. 2002 A general model for designing networks of marine reserves. *Science* **298**: 1991-1993.

Salm R. & A. Price 1995 Selection of marine protected areas. In: **Marine Protected Areas: principles and techniques for management**. Ed. S. Gubbay. Chapman and Hall, London. p15-31.

Sanchirico J. N. & J. E. Wilen 2001. The impacts of marine reserves on limited entry fisheries. In: Economics of Marine Protected Areas. Ed U. R. Sumaila, UBC Fisheries Centre Research Reports 9 (8), 2001. Vancouver, Canada. p212-222.

Sheppard R. (in press) Fish habitat area consultation with indigenous communities - the Cape York Peninsula experience. In: Proceedings of the World Conference on Aquatic Protected Areas, Cairns 2002.

Sumaila U. R. 2001. Marine protected area performance in a game theoretic model of the fishery. In: Economics of Marine Protected Areas. Ed U. R. Sumaila, UBC Fisheries Centre Research Reports 9 (8), 2001. Vancouver, Canada. p229-235.

Sumaila, U. R., Guénette, S., Alder, J., and Chuenpagdee, R. 2000. Addressing ecosystem effects of fishing using marine protected areas. *ICES Journal of Marine Science*, **57**: 752–760.

Syms C. and Carr M. 2001 Marine Protected Areas: Evaluating MPA effectiveness in an uncertain world. Paper presented to "Measuring Management Effectiveness in Marine Protected Areas Workshop", Monterey, California, May 1-3, 2001.

Vanderklift M. and Ward T. J. 2000 Using biological survey data when selecting Marine Protected Areas: an operational framework and associated risks. *Pacific Conservation Biology* **6**: 154-161

Ward T. J., Kenchington R. A., Faith D. P. & Margules C. R 1998 **Marine BioRap Guidelines: Rapid Assessment of Marine Biological Diversity**. CSIRO Australia, Perth. 52 pp.

Ward T.J., Vanderklift M.A., Nicholls A.O. & Kenchington R.A. 1999. Selecting Marine Reserves using Habitats and Species Assemblages as Surrogates for Biological Diversity *Ecological Applications* **9**: 691-698

Ward T. J., Heinemann D. & Evans N 2001. **The Role of Marine Reserves as Fisheries Management Tools: A Review of Concepts, Evidence and International Experience.** Bureau of Rural Sciences; Canberra, Australia. 192pp.

Ward T. J., Tarte D., Hegerl E. J. & Short K. 2002. **Policy Proposals and Operational Guidance for Ecosystem-Based Management of Marine Capture Fisheries**. WWF Australia, Sydney. 80 pp.

Ward T. J. 2003. **Design of a Protected Area System for the Great Barrier Reef World Heritage Area: A Review of Algorithms and Approaches**. A Report for The Great Barrier Reef Marine Park Authority (unpubl), 28p.

Ward T. J. in press. Giving up fishing grounds to reserves: the costs and benefits. Proceedings of the World Congress on Aquatic Protected Areas 2002; Cairns, August 2002

Watson R. & D. Pauly 2001. Systematic distortions in world fisheries catch trends. *Nature* 424: 534-536.

Watson R., L. Pang & D. Pauly 2001. The Marine Fisheries of China: Development and Reported Catches. Fisheries Center Research Reports 9(2). University of British Columbia, Canada. 58pp.

Whittaker M. 1999. Emerging 'triple bottom line' model for industry weighs environmental, economic, and social considerations. *Oil & Gas Journal* **97**: 23-26.

11. Glossary of Key Terms

This is a glossary of key terms often used in the literature on marine protected areas and fisheries management. (after Ward et al. 2002).

Adaptive Management
Management that adapts by learning from specific interventions designed to improve knowledge in the fishery and models of fishery structure, function and management. The process involves step-wise evolution of a flexible management system in response to feedback from within the system on biological, social or economic matters. It depends on a willingness to describe and promulgate both failures and successes in management.

Artisanal Fishery
Traditional fishery involving fishing households (as opposed to commercial companies), using relatively small amount of capital and energy, relatively small fishing vessels (if any), making short fishing trips, close to shore, mainly for local consumption. In practice, the definition varies between countries – from a one-person canoe in poor developing countries, to more than 20 m trawlers, seiners, or long-liners in developed nations. Artisanal fisheries can be subsistence or commercial fisheries, providing for local consumption or export; they may be conducted using low-impact culturally traditional fishing gear or modern fishing methods; sometimes also referred to as small-scale fisheries.

Assessment Endpoint
The combination of performance indicator and target used to determine if an activity has succeeded in response to a specific management activity or intervention.

Baseline
In monitoring, the defined natural (background) variability in a suite of indicators across space and time; the starting or natural position from which a deviation is recorded.

Benchmark
The point of reference for making a comparative evaluation of performance; the standard established for a level of performance.

Biological Diversity (biodiversity)
The variability among living organisms from all sources (including terrestrial, marine, and other ecosystems and ecological complexes of which they are part) and includes diversity within species and between species, diversity of ecosystems, and the ecological processes that maintain the ecosystems.

Biomes
A high level classification of the world's natural systems, as in ocean, grassland, forest, tundra; UNESCO has designated 14 global biomes.

Bioregions
A territory defined by a combination of biological, social and geographic criteria rather than by geopolitical considerations; more generally, a system of related, interconnected ecosystems.

Burden of Proof
The responsibility for making the case and proving that an adopted position or statement is true.

Bycatch
Bycatch is both that part of the catch that is returned to the sea either because it has no commercial value or because regulations preclude it being retained, and that part of the catch that does not reach the deck of the fishing vessel but is affected by interaction with the fishing gear.

Conservation Status
The extent to which an ecosystem, habitat or species is well protected *in situ*; takes account of threatening processes and any trends in population size or potentially threatening processes.

Consultative Council
Stakeholder groups with a focus on particular ecosystems of fisheries, such as the Pacific Whiting Conservation Council in the Pacific Northwest of the US.

Critical Habitat
Habitat that is required by a species for the normal completion of its life cycle and evolutionary development; the obligate association between a species and a habitat; the habitat that provides a vital service for species of commercial interest, as in breeding grounds or nursery areas.

Dependent Species
Species related to a focal species by ecological interaction, such as being a competitor for space, a predator or a prey of the focal species.

Ecological Integrity
The state of the ecosystem or its elements being natural, whole and unimpaired, determined by reference to appropriate ecosystem indicators and criteria.

Ecological Risk Assessment
The process of determining the ecological risks of fishing to ecosystems, and assigning priorities to consequent actions, in conjunction with partners and stakeholders.

Ecological Sustainability
The use of species or ecosystems within the capacity of the species, ecosystem or bioregion to sustain natural processes, to renew or regenerate consistent with maintaining ecosystem integrity, and ensuring that the benefits of the present use do not diminish the potential to meet the needs and aspirations of future generations.

Ecological values
The value of ecosystems, habitats and species for their biological diversity, uses (such as fishing, recreation), cultural identity, inspiration, and the provision of ecological services such as nutrient assimilation.

Ecologically-based decision rules
Decision rules in fisheries management that are designed to take account of the specific needs of ecosystems or habitats within ecosystems, or non-target species, such as top-level predators or threatened species, and/or are designed to take account of the impact of fishing on the ecosystem as an element of managing the target stock.

Ecoregions
Bioregions that are defined on mainly ecological criteria.

Ecosystem
A dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit.

Ecosystem-Based Management
Management of the uses and values of ecosystems in conjunction with stakeholders to ensure ecological integrity is maintained, and recognising that ecosystems are dynamic and inherently uncertain.

Ecosystem Function
The interactions of components of ecosystems, including energy production and consumption, transport of propagules, and biological interactions such as predation.

Ecosystem Management
A synonym for Ecosystem-Based Management; often interpreted incorrectly to imply management of ecosystems, but more correctly interpreted to mean management of human activities that affect ecosystems, often detrimentally.

Ecosystem Productivity
The flow of biomass and energy within and between trophic levels in ecosystems, habitats and species; normally includes all forms of primary and secondary production in plants and animals, including harvested species.

Ecosystem Structure
The structural components of ecosystems, including biological diversity, water and non-living substrates.

Environment
Ecosystems and their constituent parts, including people and communities, natural and physical resources, the qualities and characteristics of places and areas, and the social, economic and cultural aspects of all of these features.

Escapement
The number or proportion of fish surviving (escaping from) a given fishery at the end of the fishing season and reaching the spawning grounds or spawning size.

Eutrophication
The condition, usually limited to bays, rivers, estuaries, lakes and similar enclosed waters, where excess nutrient pollution causes undesirable, and sometimes toxic, large growths of marine plants or phytoplankton; has major impacts on biological diversity, on fishing, tourism, recreation and many other uses of coastal environments.

Externalities
Factors that originate from outside the normal range of a management system.

Fish Stock
Biological populations of species that are commercially fished, and readily traded in the seafood sector, including crustaceans, teleosts, elasmobranchs, and molluscs.

Fishery Productivity
The catch from a fishery.

Genetic Diversity
The diversity of the gene pool that resides within species and their populations.

Habitat
The place or type of site that organisms normally inhabit; may include living or non-living structures (such as seagrass or sediment).

Harvest Strategy
Describes how the harvest is intended to be controlled by management in relation to the state of some indicator of stock status. For example, a harvest strategy can describe the various values of fishing mortality to be applied in order to achieve various values of stock abundance. It formalises and summarises a management strategy. Constant catch and constant fishing mortality are two types of simple harvest strategies.

Icon Species
Species that are well known to the public or are emotive and symbolic for conservation causes, often threatened or protected species.

Important Species
Species of social, cultural, or economic significance, as well as species that have key roles in ecosystems.

Industry Sectors
High level classification of users of the marine ecosystems and oceans; includes tourism, mining, oil/gas, fishing, recreation, and many more.

Input Control (in fisheries management)
Fishery management measures imposed on 'inputs' to the fishery, such as number of vessels permitted to fish, size of gear approved for fishing, places and times where fishing is banned.

Integrated Regional Planning and Management
Planning and management organised so that processes are integrated across natural ecological boundaries, geopolitical boundaries and jurisdictions, industry sectors, and programs of government activity; regions normally are considered to be large, such as in large marine ecosystems but smaller than ocean basins.

Large Marine Ecosystem
Relatively large regions of the ocean, about 200 000 km2 or more, characterised by distinct bathymetry, hydrography, productivity, species composition, and trophically inter-dependent populations.

Limit Reference Point (LRP)
Indicates the limit beyond which the state of a fishery and/or a resource is not considered desirable or acceptable. Fishery development should be stopped before reaching the LRP. If a LRP is inadvertently reached, management action should severely curtail or stop fishery development, as appropriate, and corrective action should be taken. Stock rehabilitation programs should use the LRP as a very minimum rebuilding target to be reached before the rebuilding measures are relaxed or the fishery is re-opened.

Living Marine Resources
Marine species that may be harvested for food, shelter, or other uses such as chemicals, pigment or protein extraction.

Management
The process of controlling human activities; usually based on a coordinated system of planning, implementation and evaluation.

Management Advisory Committee
A consultative structure used in Australia to provide advice on management of a fishery; includes representatives from the fishery, science and conservation non-governmental organisations.

Management System (in fisheries management)
The institutions, the processes and the legislative or cultural basis for controlling fishing, including providing for its planning, review, assessment and information support.

Marine Protected Area
Marine area where the protection and conservation of biological diversity is the prime objective of management; includes areas that are fully protected from all human activities, 'no-take' areas, areas set aside for some forms of recreation and cultural appreciation, and areas where low-impact sustainable harvesting of natural resources is permitted.

Monitoring
The act of taking repeated measurements of indicators to ascertain the nature and extent of change over space and time; usually in accord with a plan that defines the sampling protocol, and the way in which data will be interpreted and reported.

No-Take Area
Marine protected area where the taking of living or non-living material is prohibited; may be used for low-impact recreation or tourism that is intensively managed; a Fisheries "no take" reserve created in support of a fishery.

Objective-Based Management
Management that uses agreed objectives expressed as intended outcomes as the basis for planning and control.

Output Controls (in fisheries management)
Fishery management measures imposed on 'outputs' from the fishery, such as number or weight of fish permitted to be caught, landed, or sold.

Overfishing
Catching more fish than can be supported by a sustainable fishery. There are 5 recognised types of overfishing: growth, recruitment, genetic, serial, and ecosystem.

Paleo-ecology
The science of ecology as revealed by sampling and analysis of historic data and information, often by analysis of substrate samples, fossils and ancient records.

Partner (in management)
A stakeholder who has a vital and direct interest in a fishery or the environment where it operates; includes fishers, boat owners, local conservation groups, government conservation agencies, local development agencies.

Performance Indicator
The variable being measured to determine if a level of performance has been achieved by reference to a target or benchmark level of performance; the variable measured in a monitoring program.

Phytoplankton
Microscopic mainly single-celled photosynthesising plants that live in the upper (sunlit) zones of the oceans and estuaries; they are not attached to substrate and float in the water column. population diversity The distribution of sizes, ages and the spatial distribution of individuals of a species within a population of animals, plants or microorganisms.

Precautionary Approach
Taking decisions that err on the side of conservation when there is substantial uncertainty or a significant risk that assumptions or model failure would detrimentally affect biological diversity; includes provisions in management that will ensure that all issues that may lead to significant risk to biological diversity are included within the decision-making process; implemented by ensuring that a lack of scientific certainty does not preclude decisions and consequent actions that err on the side of conservation. Includes future courses of action, which ensures prudent foresight, and to the extent possible, takes explicitly into account existing uncertainties and the potential consequences of decisions being wrong. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

Precautionary Decision Rules
Rules in fishery management that implement the principle of the precautionary approach, and specifically in relation to target fish stocks.

Productivity (in a fish stock)
Relates to the birth, growth and death rates of a stock. A highly productive stock is characterised by high birth, growth and mortality rates, and as a consequence, a high turnover and production to biomass ratios (P/B). Such stocks can usually sustain higher exploitation rates and, if depleted, could recover more rapidly than comparatively less productive stocks.

Protected Species
Species that are identified in species-specific protective legislation.

Reference Point (in fishery management)
A reference point indicates a particular state of a fishery indicator corresponding to a situation considered as desirable (target reference point, TRP) or undesirable and requiring immediate action (limit reference point, LRP, and threshold reference point, ThRP).

Resilience
The ability of ecosystems to absorb change and variation without flipping into a different state where the variables and processes controlling structure and behaviour suddenly change.

Science-Controlled (management)
Process that is dependent for implementation on progress in scientific knowledge and unable to be implemented without scientific resolution of issues (see science-supported; precautionary approach).

Science-Supported (management)
Process that is implemented using scientific knowledge in support of decisions and activities, but not controlled by progress in scientific research such that precautionary decisions cannot be made until scientific uncertainty is resolved.

Sedimentation
The infilling of rivers, bays and estuaries with sediment or other unconsolidated material, often derived from land-based activities such as inappropriate agricultural practices, but may also be caused by mining or coastal developments.

Spatial Management Framework
A set of principles, elements and constraints that, amongst others, provide a spatial structure to guide management of a natural resource within the management system.

Stakeholders
Any person, group or agency that has an interest in the fishery, its performance, or the environment where the fish live or the fishery is conducted (see Partner).

Stock Assessment
The process of collecting and analysing biological and statistical information to determine the changes in the abundance of fishery stocks in response to fishing, and, to the extent possible, to predict future trends of stock abundance. Stock assessments are based on resource surveys; knowledge of the habitat requirements, life history, and behaviour of the species; the use of environmental indices to determine impacts on stocks; and catch statistics. Stock assessments are used as a basis to assess and specify the present and probable future condition of a fishery.

Stock Assessment Models
The conceptual, statistical or process model that provides the basis for stock assessment.

Subsidies and Incentives
Mechanisms or programs invoked, usually by governments, to change behaviour of industry sectors; they may involve direct or indirect financial allocations or cost savings, support for infrastructure development, change in the taxation structure, non-monetary rewards such as prizes or appointments, and may be related to other subsidies such as fuel subsidies for all sectors.

Target
The quantitative level of a performance indicator intended to be achieved within a management system.

Threatened Species
Species that are vulnerable to extinction or are endangered.

Total Allowable Catch (TAC)
The TAC is the total catch allowed to be taken from a resource in a specified period (usually a year), as defined in the management plan. The TAC may be allocated to the stakeholders in the form of quotas as specific quantities or proportions.

Traditional Ecological Knowledge
Knowledge about ecosystems and biological diversity held by communities as a result of generations of experience with coastal living, fishing, or seafaring; may be held in written records or in oral history.

Uncertainties
Weaknesses in knowledge about aspects of ecosystems, institutions and fisheries management, and the way in which they interact; includes lack of data, lack of understanding about how processes work, and inability to predict consequences of future actions.

Virgin Biomass
Known as B_0 or B_v. The average biomass of a stock that has not been fished. The biomass of an unexploited stock. Most often inferred from stock modelling. Used as a reference value to assess the relative health of a stock, through monitoring changes in the ratio between current and virgin biomass (B/B_0). It is usually assumed that, in absence of better data, that $B = 0.30\ B_0$ is a limit below which a stock should not be driven.