more than fishy business

A literature review on the benefits of marine parks

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Contents

List of Tables

more than fishy business

1. Introduction

The concept of protected areas has evolved over time to become central to the idea of protection of our land and marine resources. Marine Protected Areas (hereafter MPAs) are designed to: (i) maintain essential ecological processes and life support systems; (ii) preserve genetic diversity; and (iii) ensure the sustainable utilization of species and ecosystems (IUCN 1994). They are officially defined by the IUCN as:

"An area of land and/or sea especially dedicated to the protection of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means" (IUCN, 1994).

This review provides an international overview of the design, principles, socio-economic conditions, and different models for MPAs. While it is acknowledged that the benefits of MPAs occur for many sectors and industries, this review explicitly highlights the benefits of MPAs to fishing.

2. Design

How decisions are made about what the MPA will protect forms the back bone of how it will operate in the future. Two elements are usually considered when designing an MPA. The first is how to classify the environmental and other values of the region so that protection is designed according to what is known as the Comprehensive, Adequate and Representative (CAR) system. CAR requires an MPA system that meets the criteria of being: (i) Comprehensive; (ii) Adequate; and (iii) Representative. These terms have been defined by the World Conservation Union (IUCN) World Commission on Protected Areas (WCPA) as part of the campaign to promote the establishment of a global representative system of marine protected areas (MPAs) as shown in Box 1.

Comprehensiveness

The MPA will include the full range of ecosystems recognised at an appropriate scale within and across each bioregion.

Adequacy

The MPA will have the required level of reservation to ensure the ecological viability and integrity of populations, species and communities.

Representative

Those marine areas that are selected for inclusion in MPAs should reasonably reflect the biotic diversity of the marine ecosystems from which they derive (ANZECC 1998).

Secondly, in order to achieve the best combination of each of these three elements, nations often pursue the establishment of a network of marine protected areas, thus capturing to the best possible extent the widest protection across all habitats and bioregions. Australia for example, has committed to the

National Representative System of Marine Protected Areas (NRSMPA) in line with the CAR principles. Specifically, the ANZECC guidelines on MPAs (ANZECC 1998, 4) determine that MPAs must be:

> "Established especially for the conservation of biodiversity (consistent with the primary goal); is able to be classified into one or more of the six IUCN Protected Area Management Categories reflecting the values and objectives of the MPA; must have secure status which can only be revoked by a Parliamentary process; and contributes to the representativeness, comprehensiveness or adequacy of the national system".

3. MPA Design

The design of MPAs is a complicated process based on considerations of size, use, anticipated and current threats and impacts, and the socio-economic profile and environmental characteristics of the region (Kelleher 1999).

The design of MPAs is also complicated by the fact that there are a number of issues inherent in marine management not experienced in terrestrial management. These include the following: (i) having a high degree of interconnectedness of the marine environment; (ii) the three dimensional aspects of management; (iii) marine areas are not static over time; (iv) sampling marine systems is very difficult; (v) there are many ownership issues in the marine environment; and overall (vi) a lack of knowledge about the marine system.

Jones and Carpenter (2009) in a paper on the design of MPAs for the UK also highlight the importance of providing ecological linkages between MPAs as part of a coherent network of MPAs overall. A MPA that is designed to be ecologically coherent is one that: (i) interacts and supports the wider environment; (ii) maintains the processes, functions and structures of their intended protected features across their natural range, (iii) functions synergistically as a whole, within which the individual protected sites benefit from each other to achieve the two objectives above and (iv) may additionally be designed to be resilient for changing conditions (Ardron et al. 2008).

Part of developing such a network is also determining what the 'gaps' are between MPAs. The focus here is on the parameters such as habitat representativity and maximum distance between MPAs (Jones and Carpenter 2009, Gaines et al. 2010). Known also as the 'rules of thumb' for MPA design principles, these principles include (McLeod et al. 2009, 362-370):

1. Bigger is better and protected areas should be at least 10-20km in diameter
2. Simple shapes (squares, rectangles) to minimize 'edge' effects
3. Units no more than 15-20 km apart
4. Protect at least 3 examples of each habitat (representation, replication, spread, catastrophe minimisation) – best practice
5. Select variety of temperature regimes to minimise future climate warming impacts
6. Protect nursery areas, spawning aggregations, areas of high uniqueness & diversity
7. Maintain functional groups (predators, herbivores, detrivores)

As Jones and Carpenter (2009, 743) note, "this approach to network design is legally and politically more defensible as it is scientifically more realistic."

MPAs are usually designed according to two basic frameworks. Firstly, a multiple-use marine park is one that within its boundaries includes a suite of zones, each offering varying degrees of protection. Higher order levels of protection are usually zones which prohibit various activities that would be perceived as destructive to the special values of that area. These zones are normally known as either "sanctuary zones" or "no-take reserves" as the aim is to prevent fishing activity. Lower order levels of protection would normally allow a range of activities within its region, including fishing, tourist activity and other uses.

Secondly, a no-take MPA system can either be a single area or a suite/network of areas that are only no-take and are declared specifically to create high level environmental protection for that region. For example, the state of Victoria, Australia, has established a system of no-take MPAs, whereas in South Australia, there is a series of multiple-use MPAs.

Importantly, in order to determine what level of protection will be declared, whether within a strictly no take or a multiple-use model, the IUCN Criteria for protection are used as a guide to delineating protection regimes. Table 2 below reproduces the definitions for the different IUCN Criteria.

Category	Description
Category I	**Protected area managed mainly for science or wilderness protection** (Strict Nature Reserve/Wilderness Area)
Category II	**Protected area managed mainly for ecosystem protection and recreation** (National Park)
Category III	**Protected area managed mainly for conservation of specific natural features** (Natural Monument)
Category IV	**Protected area managed mainly for conservation through management intervention** (Habitat/Species Management Area)
Category V	**Protected area managed mainly for landscape/seascape conservation and recreation** (Protected Landscape/ Seascape)
Category VI	**Protected area managed mainly for the sustainable use of natural ecosystems** (Managed Resource Protected Area). (IUCN, 1994)

Table 1: IUCN levels of protection

When designating the type of criteria and zone matrix for the MPA in question, there will be two issues to consider: the legal status of the MPA, and the approach. In Australia, ecosystem-based management is another framework, which is being used to manage fisheries, but is also implemented in principle for MPAs. In this context, resolving what the key boundaries will be is crucial. Establishing the baseline conditions of the areas chosen for protection is another factor.

Foley et al. (2010, 955) suggest that ecosystem-based marine spatial planning (MSP) is a process that "informs the spatial distribution of activities in the ocean so that existing and emerging uses can be maintained, use conflicts reduced and ecosystem health and services protected and sustained for future generations"' They argue the need to move away from MPA design that takes a sector by sector approach, to one such as marine spatial planning (MSP) that emphasises ecological, economic, governance and social dimensions, thus bringing planning together in an integrated way.

The advantages of this model are that it balances the diversity of human activities with an ocean's capacity to provide ecosystem services; it incorporates multiple dimensions in the planning and supports management that is coordinated at ecosystem as well as political scales.

The need to deal with context and uncertainty in MPA design is also an important theme in the literature. Contextual factors include geomorphology and biogeography, as well as type, distribution, frequency and intensity of existing and anticipated ocean uses. Similarly all ecosystems face uncertainty as part of the complex interactions between systems. While the nature of uncertainty means the implications of ecosystem change is not fully understood, the nature of human-resource interactions and the additional overlay of uncertainty created by climate change, means that MPA managers need to find ways of incorporating the uncertainty principle into their designs. This may mean the declaration of larger areas, or a more diffuse and adaptable set of management measures.

4. Integrating knowledge systems

It is important to incorporate different knowledge systems when planning, designing and implementing MPAs. For example, Scholz et al. (2004) used participatory socio-economic analysis to draw on and include fishermen's knowledge in the marine protected area planning in California.

The advantage of local ecological knowledge – or if dealing with Indigenous groups, traditional ecological knowledge - is that it is site specific, and can inform processes at a local scale (Nursey-Bray 2009, Nursey-Bray and Rist 2009). Such knowledge will often be a mixture of local, experiential and scientific knowledge, so brings dimensions to the management arrangements that otherwise would not be there.

Olsson and Folke (2001) highlight the benefits of local ecological knowledge in a case study of Lake Racken. Key to ensuring effective incorporation of different knowledge systems is how institutions behave and operate. As Jentoft (2004) argues, 'institution' is a concept with many definitions, yet it is through institutions that management operates.

The idea of how institutions operate is a central theme in the literature partly because the development of governance arrangements such as co-management has occurred worldwide in an effort to bring interests such as fishing on board, or as Noble (2000, 69-70) notes: "Co-management systems consider institutional arrangements in fisheries management as a way of decentralising resource management decisions and improving participatory democracy and compliance".

5. Socio-economic conditions

A key lesson from implementing MPAs is that while they provide biological benefits, the development and their ongoing operation are contingent on the socio-economic situation of the stakeholders within the region.

The socio-economic and cultural context within which an MPA will be implemented is an important determining factor in its viability. As Banks and Skilleter (2010) note, the success of MPAs is contingent on political commitment and agency leadership, as well as greater stakeholder involvement. Much is written about this, often focussing on the extent to which the public may be disenfranchised by the implementation of a protected area. Key themes include the issue of compensation, how to negotiate and resolve stakeholder conflict and how to build or forge socio-economic benefit from the declaration of an MPA. As Cinner et al. (2010) note, in using Kenya as a case study example, in a world facing increasing food insecurity, there is a clear imperative on managers to address socio-economic issue in their policies.

Economic viability and livelihoods are key themes within this debate (Grafton and Kompas 2005). Working out how to resolve conflict is another key issue. For example there are often conflicts between fisheries and endangered species conservation interests. There are many examples of this, such as that presented by Rauschayer, Wittmer and Berghofer (2008) of conflict in the Czech republic, Italy, Portugal, Germany and France between proponents of aquaculture and those campaigning for otter preservation in marine , estuarine and coastal protected areas.

6. Evaluation, monitoring and adaptation

In order to ascertain whether MPAs are working, and how successful they are in achieving their objectives, the implementation of monitoring, evaluation and adaptation frameworks is essential. Evaluations need to demonstrate 'results'. Increasingly, evaluations of MPAs have been based on an outcomes rather than activity based approach. While the need for evaluation is indubitable, given the wide variety of MPAS, which vary in size, management and zones across the world, it is important to recognise that no one size fits all (Day 2008). There are many other challenges. For example, where evaluations have been done, they have tended to focus on the bio-physical conditions in specific areas, rather than undertaking a holistic and inter-disciplinary investigation. Many evaluations rely on academics or research institutions and very few by management staff who have in fact been actively involved in the processes over time. Adaptive management is another area which managers within MPAs are trialling, especially in light of the uncertainty and fluidity surrounding climate change projections; the need for management in turn to be adaptable is becoming an important part of the discourse about marine management. Adaptive management can be defined as " managing according to a plan by which decisions are made and modified as a function of what is known and learned about the system, including information about the effect of previous management actions" (Parma et al. 1998).

Evaluations are important as they enhance the capacity for adaptive management, improve planning, promote accountability and encourage appropriate resource allocation. Jones (2000) outlines seven steps for evaluating effectiveness. These are presented in Table 2 below:

Table 2: Evaluating Effectiveness

Step 1: Identify management objectives
Step 2: Define key desired outcomes
Step 3: Identify performance indicators
Step 4: Undertake monitoring
Step 5: Periodically assess results
Step 6: Report findings and recommendations
Step 7: Adjust management as necessary

Day (2008) in a case study of the lessons learned from the Great Barrier Reef Marine Park region notes there are a number of lessons to be learnt from monitoring MPAs. Starting small is one of them and ensuring that a wide range of methods are considered, then applied appropriate to the situation, is crucial. Ensuring there are opportunities for participatory or community monitoring will enhance the legitimacy of the program. Adopting a precautionary approach is useful. In other words don't wait for the 'perfect' science before taking management action. Monitor management as well as the MPA itself.

7. Community based management and MPAs.

One of the key themes in MPAs is the extent to which they can provide the basis for community-based management of marine resources. Research focuses on what are the successful examples of community driven and managed MPAs. Most of the literature in this area derives from work on co-management or Commons Theory. Specifically, the key features of a successful and enduring community management program feature the following design principles (from Ostrom 1990):

1. Clearly designed geographic boundaries.
2. The development and enforcement of rules that limit resource use.
3. Congruence between rules and local conditions (i.e. scale and appropriateness).
4. Resource users have rights to make, enforce and change the rules.
5. Individuals affected by the rules can participate in changing the rules.
6. Monitoring of the resources.
7. The presence of accountability mechanisms for those monitoring the rules.
8. Sanctions that increase with repeat offences or severity of offences.
9. The presence of conflict resolution mechanisms.
10. The degree to which they are nested within other institutions.

8. MPAs and Fisheries

Existing experience suggests that more work needs to be done to explore how fishers, tour operators and other affected parties can be part of the MPA process as early as possible so they may all better understand and access the benefits of an MPA.

Studies have also shown that overall, uncertainty about the ecological values of an MPA need not be a reason not to proceed – experience shows that an imperfect MPA has more benefit than none at all.

This review also found that MPAs should be managed from both bottom-up and top-down approaches with a clearly articulated set of objectives and associated regulatory and monitoring programs so as to assess management effectiveness.

Moreover, management needs to consider adaptive management so it retains flexibility and the ability to amend/change over time, and as new and other management challenges arise (Parks 8 (2) 1998).

8.1. Extraction and Conservation

Perhaps the most dominant theme in the literature is the discussion around the tension between the need for extraction and conservation in MPAs. Biodiversity and conservation goals are the initial drivers for creating MPAs. However, these areas are also (unsurprisingly) areas of the highest resource extraction. Extractive industries include gas and oil exploration and drilling, diving, recreational fishing, commercial fishing and various forms of tourism. In particular the main conflict over MPAs is located between advocates of MPAs and commercial fishers (Kittinger et al. 2010). A fear that equity, rights, and livelihoods will be compromised underpin core arguments by fishers that oppose the declaration of MPAs.

8.2. Benefits to fisheries

A number of benefits accrue to fisheries from the establishment of MPAs. MPAs contribute to the maintenance and restoration of biological diversity and abundance of species, including fisheries. Table 3 is a summary of some of the research into the utility of MPAs, and overall these studies highlight that while benefits are not always evenly distributed across all MPAs, evidence is clearly showing that abundance, biomass, economic value, habitat and migration routes are all enhanced by the declaration of MPAs. This review also shows that time is an important determinant in MPA success, with at least 3-5 years duration needed before clear benefits are accrued. Studies also show that networks of MPAs, and MPAs that are larger and closer to each other, will yield higher economic, fisheries and biodiversity outputs overall.

Table 3: Examples of effectiveness of MPAs for fisheries

Initiative	Outcomes	Citation
Nabq Managed Reserve Protected Area, Gulf of Aqaba Network of no-take zones (NTZ), established 1995 to promote the sustainable management of fin fish stocks Surveys undertaken of molluscs and echinoderms across NTZ and adjacent fishing zones (2000 – 2002).	Pooled data from 3 years showed significantly higher abundances of *Tridanca* and *tectus dentatus* in NTZ with a greater abundance in reef edge zone also showed greater frequency relating to size range and frequency.	Ashworth *et. al.* (2004)
Spiny Lobster – *Janus edwardsii* –	Increased abundance and greater biomass in reserves in New Zealand and Tasmania.	Edgar and Barrett (1999), Kelly *et. al.* (2000)
Abalone, scallops and clams.	Showed increase in abundance in areas closed to fishing.	Rice *et. al.* (1989), Edgar and Barrett (1999), Wallace (1999), Murawski *et. al.* (2000), Rogers-Bennett and Pearse (2001)
Small scale annual closure of gastropod mollusc fishing in Chile.	Increased CPUE when fishing reopened, and mean size and CPUE of three exploited invertebrates was higher in a managed area than outside.	Castilla and Fernandez *et. al.* (1998)
Nabq Managed Reserve Protected Area case study of 8 families of reef fish, at 3 m depth across NTZ, and for a limited direction in adjacent fish zones.	Effects of NTZ changed with water depth as most fishing occurred in shallow water. Reef fish – 7 of the 8 species increased in abundance in NTZ. Evidence of spill-over found and in 6/8 species significant drop in abundance was found as moved away from centre of NTZ. "spill-over may occur to an extent and in a direction depending on the trophic group and fishing intensity".	Ashworth and Ormond (2005)
There are 4600 MPAs with some level of protection.	Of these only 0.08 are no-take.	Banks and Skilletter (2009)
Densities of macrobenthic invertebrates and macroalga in 4 Tasmania NTZ MPAs were monitored over 10 years, after MPA establishment.	Factors affected were mean size, abundance of rock lobster, and abundance of prey such as urchins and abalone "Our results reflect the importance of long-term monitoring and the value of MPAs when sufficiently large as reference areas for determining and understanding ecosystem effects of fishing in the absence of historical baseline data".	Shears *et. al.* (2006)
Assessed effect of NTZ on reef fish assemblages in the north West Mediterranean – it is a 3 year survey, that modelled diversity and abundance within the assemblage.	Apart from small fish individuals, inside/outside differences in species abundance were significantly affected by MPA estates; abundance increased on average in the reserve. Results were more significant for large to medium sized fish. Benefits of MPAs to fished species do accrue but do not apply to all species at all times and are highly variable amongst taxa. Benefits are clear, though, after 6 years of MPA establishment.	Claudet, *et. al.* (2006)

Measured reef fish spill-over from NTZ in Itacolomi Reef, eastern Brazil, estimating biomass and body size by the reserve boundary before 2001 and after 2002 – 2005 protection. Replication with some unprotected sites, and according to 3 distance categories – 0 – 400, 400 – 800 and 800 – 1200 m. Habitat measures taken.	Biomass of major fish resources low at first but increased by 2003. Results offset by illegal poaching so suggest MPAs also need ongoing monitoring and incorporation of socio-economic aspects to be fully effective.	Francini-Filho, and Moura (2008)
Review of MPAs which also reported on project that trialled BACIP analysis (Before – After – Control – Impact) on 3 marine reserves.	* Tsitsikamma National Park, South Africa MPA established 1964, densities of commercially important fish (sparid) was 42 times higher than in nearby fishing grounds * Scandoli Nature Reserve in Corsica – densities of 11 fish species were 5 times higher than fishing site after 13 years protection. * Columbretes Island Marine Reserve Spain; experimental CPUE found stocks were 6 – 58 times greater than unfished sites including the Pen Shell being 12 times greater in abundance than in 100 ha of no-take. *Other examples cited in article* * 7 fold increase in larger predatory fish after protection for 1 year in the Apo Island Philippines. * New Zealand's temperate rocky reef reserves protected for 5 – 20 years found snapper were greater than the minimum legal size and are 14 times more abundant than in fishing areas. * After 5 years, 35% of blue cod on Long Island Kakomuhua Reserve were 33 cm vs. less than 1% in the nearby area. * Maria Island Reserve, Tasmania, lung fish were more than 3 times more common after 6 years protection. * Everglades, Florida, modal size of grey snapper was 25 – 35 cm larger than in exploited areas. * Edmunds Underwater Park USA, after more than 20 years protection, cod produced 20 times more eggs than in adjacent fishing area. * Copper rock fish are 100 times more abundant and 70% of biomass of fish in Kenya's Mombasa Marine National Park are reproductively active compared with 20% in nearby fishing areas * Fiji clam closures resulted in a dramatic increase in the number and size of clams were 13 times more abundance in just 3 years. After 5 years, 19 times abundant. Other possible effects- being able to continue traditional practice. * St Lucia stocks of 5 families of exploited reef fish tripled in biomass in reserves within 5 years of protection. * De Hoop Marine Reserve South Africa, experimental fishing – CPUE, order of magnitude shows that sites are affected after 7 years. * Florida Keys: densities of yellowbill snapper increased by 15 times in sanctuaries areas after 4 years. * Cape Canaveral, Florida, 40 Km square was closed in 1962 due to the Kennedy Space centre: Effects on recreational fishing within 20 km of stretch of coast around the reserve, 62% of recorded breaking black drum, 54% of record breaking red rum and 50% of spotted sea trout found. * MPAs can protect migration routes – Blue Crab in Chesapeake Bay, USA, only spawning areas protected within reserves, and its deep water spawning migration route, for females could help survive/ enhance sustainability of fishing; the spill-over effects of juvenile/adults, export of egg/larvae, and migration routes	Gell and Roberts (2003) (good review of many MPAs)

Chile - 3 year closure for squat lobster.	Increased biomass, re-expansion of species into area 50 km into areas previously depleted largely due to larval dispersion from MPAs – conclusion here is that MPAs should be relatively close or connected.	Roa, R & Bahamonde (1993)
Study to quantify the number and biomass of individuals annually spilling over from an MPA and their contribution to the local fishery catches. Decade of tag recapture (1997 – 2007) for the lobster on Colombretes Islands Marine reserve.	Showed that during 8 - 17 years protection, harvested spill-over offset the loss of yield resulting from reduction of fishing grounds, producing mean annual net benefit of 20% of species: what they did not make up for in numbers they did in weight as individuals were much larger.	Goni *et. al.* (2010), Goni *et. al.* (2001, 2001a, 2006)
Six Mediterranean MPAs reviewed.	Effect of reserve: evidence a higher value of fish species richness, abundance and biomass compared with inside to outside.	Harmelin-Vivien *et. al.* (2008)
Economic assessment of benefits of networks of marine conservation zones in UK offshore waters, used to help process inform the UK Marine Coastal Access Bill.	Estimate benefits range from designations of between 10.2 billion pounds and 23.5 billion pounds in present values and applying a 3.5% discount rate.	Hussain *et. al.* (2010), Sanchirico *et. al.* (2002)
Survey of fisher views about MPAs in UK.	Found fishers held a diversity of views around and that it would be worth talking to fishers and working with them in development of MPAs.	Jones (2007)
Looked at persistence and growth rate for small populations to determine conditions that will yield greater growth rate.	Found that minimal fraction of habitats needed to be off-limits to fishing, and it depends on the birth and death rate in habitats and fisheries. Suggested that MPAs are appropriate for mobile species that have (i) small movement rates, (ii) high birth rates to fishing rates (iii) large habitat sizes.	Malvadkar and Hastings (2008)
Looking at whether species that change sex are benefited by MPAs.	Meta analysis of ratio of fish abundances inside versus outside MPAs show initially not much difference. However reserves, over more than 10 years, show that female first sex changers considerably benefit from MPAs.	Molloy, *et. al.* (2008)
Lyme Bay, UK July 2008, 206km square declared.	For it to be win-win, MPA must be based on long-term goal based on thorough evaluation of the environmental, social and economic values for marine biodiversity.	Rees *et. al.* (2001)
Spatial analysis of the benefits of Medes Island Marine Reserve.	Effects of trends reflecting habitat heterogeneity, spatial restructuring of data on spatial predictions of fish catch per unit effort. CPUE of total fish, and length increased closer to the reserve, especially the common pandora and the striped red mullet.	Stelzenmuller, *et. al.* (2007)
Suggest fishing should be closed in all spawning areas and at least 50% of adjacent areas:case study of Leopard Groper.	High non-consumptive benefits also accrue and due to divers coming to watch groper significant economic benefits have accrued in the local community. Adaptive management schemes could well provide a way to incorporate recurring information and shifting baselines.	Wielgus *et. al.* (2008)
Surveys of 10 sites inside and outside of Bahaman marine reserve over 2.5 years. Investigating whether reductions in macroalga cover associated with recovery of herbivorous parrot fish within reserve can help recovery.	Increases in coral cover; and macro algal cover negatively correlated with change in total coral over time.	Mumby and Harborne (2010)

Project to count shark populations in no go zones in GBR.	Densities of white tip sharks twice as high in sancturay zoned reefs as on general use zoned reefs; twice as high on sink reefs and grey reef sharks four times more abundant on sanctuary zoned reefs as on general managed use zoned reefs. 1.5 times more common coral trout on sanctuary zoned reefs. Differences reflect real difference in fishing effort across zones.	Ayling and Choat (2008)
Influence of zoning on fish communities of deep reef bases of southern GBRMPA. 2009 survey of 16 pairs of large discrete deep water reef bases in southern GBRMPA.	Zoning had a significant effect on the observed *MaxN*, but this was detectable mainly in habitats dominated by corals. In this habitat type, 'target' species were about 1.5 times, and unfished species about 1.9 times, as abundant in the sanctuary zones as the same groups in the genral managed use zones. Individual species showed distinct responses, with grey reef sharks (taken as by-catch) having higher *MaxN* in a range of habitat types on sanctuary zoned reefs, and the Venus tusk fish having lower *MaxN* on sanctuary zoned. The prized deep-water coral trout, red emperor and red-throat emperor had higher *MaxN* values around the sanctuary zoned reef in coral dominated habitats, but not by large margins. For every ten BRUVS sets, there were about eleven coral trout, six red emperor and five grey reef sharks more in sanctuary zones than in similar coral dominated habitats of general managed use zones.	Cappo *et. al.* (2008)
Benthic (video quadrats) and associated fish communities (underwater visual censuses) in a well-enforced reserve in the Bahamas.	Robust reserve effects were limited to Montastraea reefs. The reserve supported an average of ≈ 15% more fish species per site compared to outside the reserve. This pattern was particularly driven by more large-bodied grouper, damselfish, and butterfly fish species inside the reserve. Increases in fish biomass and differences in community structure inside the reserve were limited to large-bodied groupers.	Harborne *et. al.* (2008)
Seasonal surveys (Autumn/Spring 2007) on two pairs of discrete deepwater shoals in the southern Great Barrier Reef. Within each pair, one shoal was re-zoned 'Green' (closed to all fishing) in 2004 while the other 'Blue' (open to fishing) remained open to fishing.	Analyses showed that there was a clear effect of zoning, where the mean abundance index of species primarily targeted by fishing in the blue zone were half those of the same species in green zones that were closed to fishing in 2004. Abundance ratios of these species in green and blue zones varied from 1.1 to 11.9 (geometric mean = 2.8) and ratios of 5 of the most targeted species were significantly greater in green than blue zones including red emperor (*Lutjanus sebae*), red throat emperor (*Lethrinus miniatus*), venus tuskfish (*Choerodon venustus*), spangled emperor (*Lethrinus nebulosus*) and golden spot hogfish (*Bodianus perditio*).	Stowar M, *et. al.*. (2008)
Impact of MPAs on Crown of Thorns Starfish predation.	Relative frequency of outbreaks on reefs that were open to fishing was 3.75 times more than that on no-take reefs in the mid-shelf region of the GBR, where most outbreaks occur.	Sweatman H (2008)

Rottnest Island, Western Australia.	Surveys of spiny lobster (*Panulirus cygnus*) populations in shallow waters surrounding Rottnest Island in Western Australia revealed much higher levels of density, biomass and egg production in no-take than in fished areas. Density of lobsters was ~34 times higher in the sanctuary, and density of lobsters above minimum legal size around 50 times higher than in other areas around the island where recreational fishing is allowed. Mean carapace length (CL), total biomass and egg production of lobsters in the sanctuary zone were significantly higher than in adjacent fished areas. Large individuals (≥100 mm CL), especially large males, were found almost exclusively within the sanctuary.	Babcock, *et. al.* (2007)
Nekton diversity and community composition in subtropical eastern Australia.	No statistical significant difference was detected in species richness between the areas however species evenness was significantly lower in the only non-reserve site impacted by commercial net fishing. Mean size of nekton was found to be significantly greater in the marine reserves compared to non-reserves but no statistical significant difference was found in the density of nekton between the study sites.	Pillans *et. al.* (2007)
Philippines - examined spatial patterns of abundance of fish across two ~900 m long sections of coral reef slope at each of two small Philippine islands (Apo and Balicasag). One section sampled the entire length of a no-take reserve and extended 200-400 m outside the two lateral reserve boundaries. The other section, without a reserve, was a control. The reserves had had 20 (Apo) and 15 (Balicasag) years of protection when sampled in 2002.	Abundance of target fish declined sharply 50 m outside the ARNB Density of sedentary target fish declined 2-6 times faster than density of highly mobile and mobile target fish across the ARNB.	Abesamis *et. al*. (2006)
Study designed to examine potential of no take reserves to re-establish predatory interactions and rocky reef interactions, Mediterranean.	Protected locations supported higher density and size of the most effective fish preying on sea urchins (the sea breams *Diplodus sargus* and *D. vulgaris*) than unprotected locations. Density of sea urchins (*Paracentrotus lividus* and *Arbacia lixula*) was lower at protected than at unprotected locations. These results suggest that (1) depletion and size reduction of predatory fish caused by fishing alter patterns of predation on sea urchins, and that (2) fishing bans (e.g., within no-take marine reserves) may re-establish lost interactions among strongly interactive species in temperate rocky reefs with potential community-wide effects.	Guidetti (2006)
No-take versus partial protection: long-term data (1977–2005) from before and after park establishment, on the abundance of spiny lobster Jasus edwardsii from fixed sites in a no-take marine park and a recreationally fished marine park.	Lobster densities were comparable between both marine parks prior to park establishment, but the response of lobster populations differed markedly following protection. On average, legal-sized lobster were eleven times more abundant and biomass 25 times higher in the no-take marine park following its establishment, while in the partially protected marine park there has been no significant change in lobster numbers.	Shears *et. al.* (2006)

Apo Island, Philippines: density-dependent export of a planktivorous reef fish, *Naso vlamingii*.	Mean density of *N. vlamingii* increased threefold inside the reserve between 1983 and 2003. Modal size in the reserve increased from 35 to 45 cm total length over 20 years of protection. In addition, both density and modal size increased outside the reserve close to (200–300 m), but not farther from (300–500 m), the reserve boundary over the 20 years of reserve protection.	Abesamis and Russ (2005)
Manipulations of reserve status, and yield estimates, were made at two Philippine islands over two decades. Twenty-five percent and ten percent, respectively, of the coral reefs at Sumilon and Apo islands were made no-take reserves in 1974 and 1982.	Biomass of target fish increased inside the no-take reserves 3- to 4.5 fold over 9–18 years. Biomass did not increase outside each reserve. Protection of the Sumilon reserve ceased in 1984. Biomass of targeted fish in the reserve and trap and gillnet catches of these fish declined by 42.7% and 40%, respectively, by 1985. The reserve was re-protected from 1987 to 1991 and from 1995 to 2001. Fish biomass increased in the reserve by 27.2%.	Alcala *et. al.* (2005)
Response of snapper *Pagrus auratus* to the establishment of no-take status in a marine reserve around the Poor Knights Islands in north eastern New Zealand.	Snapper showed significant increases in abundance and biomass relative to fished control locations. This was particularly apparent for large snapper (>270 mm), whose numbers increased rapidly to levels 7.4 times higher in the final survey compared to the initial pre-reserve survey, and total snapper biomass increased by 818%. There was no significant increase in the abundance, biomass or size of snapper at the reference locations over this time.	Denny *et. al.* (2004)
Larger biomass of targeted reef fish in no-take marine reserves on the Great Barrier Reef, Australia.	Densities of *Plectropomus* spp. and *Lutjanus carponotatus,* both targeted by fisheries, were much higher in protected zones than fished zones in two of the three island groups. *Plectropomus* spp. were 3.6 and 2.3 times more abundant in protected than fished zones of the Palm and Whitsunday island groups. *L. carponotatus* were 2.3 and 2.2 times more abundant in protected zones than fished zones of the Whitsunday and Keppel island groups.	Evans and Russ (2004)
Sumilon and Apo Islands, Philippines, 1983 - 2000.	The biomass of large predatory fish was still increasing exponentially after 9 and 18 years of protection at Sumilon and Apo reserves, respectively.	Russ and Alcala (2004)
Sumilon and Apo Islands.	Underwater visual census done re biomass of *Acanthuridae* (surgeonfish) and *Carangidae* (jacks). Showed that two families of reef fish that account for 40–75% of the fishery yield from Apo Island, Philippines, tripled in a well-protected no-take reserve over 18 years (1983–2001). Biomass of these families did not change significantly over the same period at a site open to fishing.	Russ *et. al.* (2004)

Quantitative estimates of density and biomass of coral trout, *Plectropomus* spp., the major target of the hook and line fisheries on the Great Barrier Reef (GBR), Australia, on inshore fringing reefs of the Palm and Whitsunday Island groups, central GBR, are provided for 3-4 years before (1983-1984), and 12-13 years after (1999-2000) the establishment of no-take reserves in 1987.	Density and biomass of coral trout increased significantly (by factors of 5.9 and 6.3 in the Palm Islands, and 4.0 and 6.2 in the Whitsunday Islands) in the reserve sites, but not the fished sites, between 1983-1984 and 1999-2000. In 1999-2000, density and biomass of coral trout and a secondary target of the fisheries, *Lutjanus carponotatus,* were significantly higher in the protected zones than in the fished zones at both island groups.	Williamson *et. al.* (2004)
Do marine reserves work?	The results of 89 separate studies show that, on average, with the exception of invertebrate biomass and size, values for all four biological measures are significantly higher inside reserves compared to outside (or after reserve establishment vs. before) when evaluated for both the overall communities and by each functional group within these communities (carnivorous fishes, herbivorous fishes, planktivorous fishes/invertebrate eaters, and invertebrates). Results also show that the relative impacts of reserves, such as the proportional differences in density or biomass, are independent of reserve size, suggesting that the effects of marine reserves increase directly rather than proportionally with the size of a reserve.	Halpern (2003)
Compared assemblages of targeted fish from coral reef habitats in sanctuary (no-fishing) and recreationally fished zones of a marine protected area (MPA).	Found significantly greater biomass, size, and abundance of legal-sized *lethrinids* (the most targeted family in the region) in sanctuary zones, but no differences in other families/genera. Cover of *Acropora* coral and hard substrate differed between zones at some regions but differences were inconsistent. There were no significant differences in algal cover between zones. Possible that recreational fishing pressure may have capacity to deplete fish populations below that of adjacent protected areas. The effect of recreational fishing in coral reef habitats may be greater than previously thought.	Westera *et. al.* (2003)
Mediterranean hake (*Merluccius merluccius*).	A marine reserve could be highly beneficial for this species. Study shows benefits from reserves not just for overexploited stocks of low-mobility species, but also (to a lesser extent) for underexploited stocks and high-mobility species. Greatly increased resilience to overfishing is also found in the majority of cases.	Apostolaki *et. al.* (2002)
Marine reserves in Florida (United States) and St. Lucia.	Within 5 years of creation, a network of small reserves in St. Lucia increased adjacent catches of artisanal fishers by between 46 % and 90%, depending on the type of gear the fishers used. In Florida, reserve zones in the Merritt Island National Wildlife Refuge have supplied increasing numbers of world record sized fish to adjacent recreational fisheries since the 1970s.	Roberts *et. al.* (2001)
MPAs and benefits to fisheries.	Report that sums up results of empirical studies of marine reserves to assess the potential benefits of protection for fish populations. Demonstrate that the overall abundance of fishes inside reserves is, on average, 3.7 times higher than outside reserve boundaries.	Mosquera *et. al.* (2000)
New Caledonia: commercial fish communities and *Chaetodontidae,* sampled before fishing prohibition and after five years of protection, were compared.	Found significant increases in the species richness, density and biomass of the major exploited fish families (*Serranidae, Lutjanidae, Lethrinidae, Mullidae, Labridae, Scaridae, Siganidae and Acanthuridae*) and also of the *Chaetodontidae*.	Wantiez *et. al.* (1997)

Estimated the abundance and size of fishes by trapping and visual census on fringing reefs in Barbados: 5 reefs within the 2.2 km of the Barbados Marine Reserve (BMR) and 8 reefs in the non-reserve (NR) area within 4 km of the reserve boundaries.	The abundance of large, trappable size fish of all species combined was higher in the BMR than in the NR, but abundance of small, non trappable fish did not differ between BMR and NR. BMR does protect the fish community from fishing mortality and that emigration rates are generally low.	Rakitin and Kramer (1996)
Caribbean marine reserves -coral-reef fish communities of Saba Manne Park (Netherlands Antilles) and Hol Chan Marine Reserve (Ambergns Caye, Belize) in the Caribbean to assess differences between them and adjacent ecologically similar sites after 4 years of protection from fishing.	45% of target species commonly recorded in visual censuses in Belize (23 % of all recorded target species), and 59% at Saba (22 %) showed greater abundance size or biomass in shallow protected sites. These differences are considered primarily to reflect increased survivorship with the cessation of fishing mortality. The greatest estimated biomasses were observed in locally protected snapper (*Lutlanidae*) in Belize and Saba and grunt (*Haemuhdae*) at Saba. In both protected areas the local stock of visible demersal target fishes 19 to 20 times greater in biomass and 22 to 35 times greater in commercial value than in fished sites.	Polunin and Roberts (1993)
Great Barrier Reef Marine Park	Before and after study shows that while there is variation between regions and cross shef locations due to differences in ecology and intensity of exploitation, that (i) no take zones in the GBR benefit fish stocks with up to 2 fold increases in numbers and size of fish on many no take reefs, (ii) that no take reefs generally have larger/older fish for the target species and that (iii) ecosystem effects occur where no take zones are benefiting overall fish populations, not just those individual fish populations in no take areas.	McCook et al (2010)
Tasmania	Densities of macrobenthic invertebrates and macro-algae in four Tasmanian 'no-take' marine protected areas (MPAs) were monitored annually for 10 years following MPA establishment, with changes compared to those at external (fished) reference locations. Fishing substantially influenced the population characteristics of many species, including altering the mean size and abundance of rock lobsters and the abundance of prey species such as urchins and abalone. Strong declines in abundances of purple urchins and abalone within the largest MPA at Maria Island indicate likely indirect effects related to protection of predators from fishing. The two smallest MPAs (ca. 1 km coastal span) generated few detectable changes. Our results affirm the importance of long-term monitoring and the value of MPAs, when sufficiently large, as reference areas for determining and understanding ecosystem effects of fishing in the absence of historical baseline.	Barrett, N., Buxton, C., Edgar, G (2009)

9. Conclusion

Marine protected areas are proven to conserve marine life whilst providing a major boost to fisheries and other industries such as marine tourism. This review has highlighted that if MPAs are designed well, and implemented in accordance with international standards they reap multiple environmental and socio-economic benefits.

Experience also shows that successful implementation of MPAs and their ongoing maintenance will only occur with the full participation of the affected community.

This review shows that across the world MPAs have in fact acted as effective fisheries management tools in temperate and tropical regions. The establishment of MPAS is indeed 'much more than fishy business', and provides real social and economic benefits that go beyond biodiversity outcomes.

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