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Marine Protected Areas
A review of their use for delivering marine biodiversity benefits

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Cover note

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Summary

Marine Protected Areas (MPAs) are an established part of marine conservation programmes around the world. In the UK, most MPAs are referred to as 'European marine sites' which are Special Areas of Conservation or Special Protection Areas as defined by the EU Birds Directive and the EU Habitats Directives.

The UK is committed to identifying and designating relevant areas of the UK's seas as areas of marine protection belonging to "a network of well-managed sites by 2010". As part of this, the Government is also considering what role MPAs can play in ensuring functioning and resilient ecosystems and the protection of biodiversity.

This report examines the evidence for benefits from MPAs set up for the conservation of marine biodiversity and across the full spectrum of management regimes from Highly Protected Marine Reserves (HPMRs), where all extraction is prohibited, to multiple-use management areas.

Evidence for the beneficial effects of MPAs is described in relation to:

- conservation of biodiversity;
- habitat protection;
- commercial species (as a result of biodiversity conservation measures rather than fish stock management);
- protection or enhancement of ecosystem services; and
- insurance against environmental or management uncertainty.

The value of MPAs for scientific research, education and raising awareness about the marine environment are also touched on briefly.

The most systematic analysis of MPA effects to date, where there is good comparable data for HPMRs suggests overwhelming positive effects on biodiversity. These were apparent as higher densities, biomass, size and diversity of certain species or groups of species within HPMRs compared to outside them, or after reserve establishment compared to before. These benefits have also been reported from multiple-use MPAs which include HPMRs. There is also some evidence of positive species community effects such as greater complexity of food webs and increased primary and secondary productivity in MPAs as a consequence of protection.

Reported habitat protection benefits of MPAs fall into two categories: preventing or reducing the impact of human activities; and providing conditions free from recurring impact thus allowing time and space for recovery and restoration. There is an abundance of evidence from studies carried out in the UK as well as other parts of the world that particular activities have damaging effects on marine habitats and that, in some cases at least, 'recovery' to pre-impact conditions is possible when those activities are discontinued.

The most direct evidence that MPAs can protect and enhance ecosystem services comes from situations where habitats and species protected by MPAs are known to provide specific ecosystem services whether in HPMRs or multiple-use MPAs. By way of illustration, the

report presents evidence on the role of seagrass beds, kelp forests, mussel beds, maerl beds and sediment communities in supporting ecosystem services such as productivity, sedimentation, stablisation, oxygenation, shoreline protection, sediment production and nutrient recycling.

The potential for MPAs to act as insurance against environmental or management uncertainty is promoted as a biodiversity conservation benefit. This role has also been agreed as an objective of individual MPAs but has still to be tested.

There are many examples of MPAs being used for scientific investigation and education. HPMRs have been used as reference sites for monitoring the impacts of human activities, for example, while the UK Marine SACs LIFE Project has shown the educational potential and and use of multiple-use MPAs.

Not all studies into the effects of individual MPAs reveal positive effects on marine biodiversity. Negative effects may result from attracting activities into an MPA or increasing pressure outside the MPA by displacing activities. Within MPAs negative effects are most likely to be due to poor management or limited understanding of the carrying capacity of the site. Impacts outside MPAs demonstrate problems with the wider management regime rather than failure of the MPA. They highlight the importance of MPAs being set into a wider integrated marine management context rather than isolated islands of biodiversity conservation.

MPAs have many roles and are one of a number of management tools which can be used for the conservation of marine biodiversity. This report provides evidence of many positive effects of MPAs on marine biodiversity. The conclusion is that there is overwhelming evidence of the benefits of MPAs for marine biodiversity and that these benefits are clearest and most significant in the case of Highly Protected Marine Reserves.

Contents

1 Introduction

The UK Government has outlined its vision for the marine environment as one of "clean, healthy, safe, productive and biologically diverse oceans and seas". The Ecosystem Approach (Convention on Biological Diversity 2003) is at the heart of the strategy to achieve this, alongside policies that promote sustainable development, integrated management, stakeholder involvement, robust science and the precautionary principle (Defra 2002).

To deliver this vision the Government is considering the use of Marine Protected Areas (MPAs) and what role they could play in delivering the Government vision and objectives for the marine environment. This report is intended to inform that process by drawing together current evidence from the scientific literature on the role of MPAs in the conservation of marine biodiversity. The potential role of MPAs in delivering social and economic benefits are not discussed in detail within the context of this report but education and research benefits are discussed to some degree.

2 Marine Protected Areas

There are many interpretations of what is meant by a Marine Protected Area (MPA) with the term being used generically to describe sites with different objectives and different degrees and types of protection. There is also scope for confusion because the term MPA is used interchangeably with local names for protected areas such as 'nature reserve', 'marine park' and 'whale sanctuary'. In the UK, MPAs include European marine sites (Special Areas of Conservation or Special Protection Areas as defined by the EU Birds and Habitats Directives) (there are currently twenty-three marine Special Areas of Conservation in England), 'Marine Nature Reserves' (of which there are currently three) and 'voluntary marine conservation areas' and some Sites of Special Scientific Interest (SSSIs). Some areas managed for fisheries are also described as MPAs but this report focuses on MPAs where the principle objective is conservation of biodiversity.

The World Conservation Union (IUCN) has defined Marine Protected Areas as:

"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." (IUCN 1988).

Within this definition, and using a system developed by IUCN, Marine Protected Areas may be divided into six types according to their objectives (IUCN 1994). Category I sites have the highest level of protection and are sometimes described as 'No-Take Zones' or 'Highly Protected Marine Reserves (HPMR)'. In these areas, all extractive activities are prohibited and there may also be restrictions on access. Category VI areas can include any or all of the other categories. Many MPAs are 'multiple use' ie include areas for conservation, recreation and sustainable use and as such may have HPMRs within the boundary.

The relationship between UK biodiversity conservation designations and the IUCN international classification scheme for protected areas is presented in Table 1.

Table 1 IUCN Categories of Protected Areas and the UK statutory designations for biodiversity conservation which **may** be used to achieve the same objectives in the marine environment *

Category	Objective	UK designations	Example
Category I	Protected area managed mainly for science or wilderness protection	Marine Nature Reserve (MNR)	None of the existing MNRs have this as an overall objective but the Lundy No-Take Zone (within the MNR) is Category I.
Category II	Protected area managed mainly for ecosystem protection and recreation	N/A	No UK MPAs have this as an overall objective
Category III	Protected area managed mainly for conservation of specific natural features	Special Area of Conservation; Special Protection Area; Marine Nature Reserve; Site of Special Scientific Interest (SSSI)	The Fal estuary SAC with objectives to maintain large shallow inlets and bay, subtidal sandbanks, intertidal sand and mudflats and Atlantic salt meadows in favourable condition taking account of natural change.
Category IV	Protected area managed mainly for conservation through management intervention.	Special Area of Conservation; Special Protection Area; Marine Nature Reserve; SSSI	Morecambe Bay SPA with objective to maintain internationally important populations of Sandwich terns and regularly occurring migratory species as well as internationally important assemblages of waterfowl and seabirds and (under the Birds Directive)
Category V	Protected area managed mainly for landscape/seascape conservation and recreation.	Coastal and Marine National Park (Scotland); Area of Outstanding Natural Beauty	None designated as yet but provisions in Scottish legislation.
Category VI	Protected area managed for the sustainable use of natural ecosystems.	Special Area of Conservation; Special Protection Area; Marine Nature Reserve	Lundy Island MNR where the overall goal is to manage the protected area for the benefit of the wildlife and to actively promote the ecologically sustainable use of resources and the use of the reserve for education and enjoyment of all aspects of marine conservation.

* This table does not include voluntary initiatives or spatial management tools used by other sectoral interests (eg. static gear reserves, fisheries boxes & Particularly Sensitive Sea Areas) that may also help to achieve the stated objectives.

The UK Government is considering what role MPAs can play in ensuring functioning and resilient ecosystems and the protection of biodiversity. All of the IUCN categories of MPAs and all UK biodiversity conservation designations have objectives relevant to this task although the effectiveness for delivery will vary depending on the level of protection and the management mechanisms available.

2.1 The role of Marine Protected Areas

MPAs are used in a variety ways. The World Parks Congress noted that properly designed and managed MPAs play important roles in:

- conserving representative samples of biological diversity and associated ecosystems;
- protecting critical sites for reproduction and growth of species;
- protecting sites with minimal direct human impact to help them recover from human impact and other stresses such as increased ocean temperature;
- protecting settlement and growth areas for marine species so as to provide spill-over benefits to adjacent areas;
- providing focal points for education about marine ecosystems and human interactions with them;
- providing sites for nature-based recreation and tourism; and
- providing undisturbed control or reference sites serving as a baseline for scientific research and for the design and evaluation of management of other areas.

Key ways in which MPAs could fulfil these roles are by:

- maintaining ecological processes and life support systems;
- preserving genetic diversity;
- supporting sustainable use;
- maintaining natural areas for education and research; and
- providing social and economic benefits.

In the UK these types of actions could contribute to protecting marine biodiversity, making best use of marine science, sustainable fisheries, work on marine ecosystem indicators and other Government commitments set out in the UK strategy for the conservation and sustainable development of the marine environment (Defra 2002).

This report illustrates and provides evidence of how existing MPAs fulfil the roles specific to the protection marine biodiversity. It should be noted that MPAs are one of a number of management tools all of which are required to deliver protection of marine biodiversity and that they will not remove the need for sustainable management of activities taking place outside their boundaries.

2.2 Goals and objectives of Marine Protected Areas

The goals and objectives of MPAs are many and varied however there are seven main areas outlined in Box 1. Conservation of biological diversity and productivity are the main reasons for establishing many MPAs (IUCN 1999) but these are rarely the only reason (Box 1). MPAs can have research, social and economic goals and objectives, as well as objectives concerned with the establishment and effective management of the protected area.

Box 1. Typical goals and objectives of MPAs

- Conservation of biodiversity and habitat
- Fisheries management
- Increasing scientific knowledge
- Providing educational opportunities
- Enhancing recreational activities and tourism
- Sustaining environmental benefits from ecosystems
- Protecting cultural heritage

(Anon 2002; Pomeroy, Parks & Watson 2004)

As part of the management cycle associated with MPAs there is a need to evaluate whether the targets for the site have been met in order to assess the degree to which the goals and objectives have been achieved. A four volume global review of MPAs published in 1995 examined management at 383 MPAs (Kelleher, Bleakley & Wells, 1995). Of these, only 155 [40%] were assessed as generally achieving their management objectives. Systematic evaluation tools have since been developed by IUCN in collaboration with WWF and NOAA (Pomeroy, Parks & Watson 2004) and by the World Bank (World Bank 2004). Once applied, they should help give a global overview of how well MPAs are achieving their objectives. In the meantime, this type of information is available for individual sites or regions.

2.3 Marine Protected Area networks

The need to establish networks of MPAs to conserve marine ecosystems and biodiversity is enshrined in a number of international conventions and agreements to which the UK is a signatory. They include the Convention on Biological Diversity, the 2002 World Summit on Sustainable Development (World Parks Congress 2005), and Annex V of the OSPAR Convention. The UK is committed to identifying and designating relevant areas of the UK's seas as areas of marine protection belonging to "a network of well-managed sites by 2010" (Defra 2002).

A network of MPAs is a collection of individual sites that are connected in some way by ecological or other processes (CBD 2004) eg migration routes, areas important for different life stages of a particular species such as nursery grounds and spawning areas (Palumbi 2003), or sites with a physical connection within an ocean current. Networks can also be designed to be resilient to changing conditions" (OSPAR 2005). Draft guidance on developing an ecologically coherent network of OSPAR marine protected areas (still to be adopted) states that "A network is characterised by a coherence in purpose and by the connections between its constituent parts". The UK is working through the OSPAR

Convention to contribute to a network of ecological coherent and well managed MPAs and determining what would be required from such a network (Defra 2005a).

The scientific literature on MPA networks includes papers on the theory of establishing networks, criteria to evaluate whether proposed sites form part of a network and modelling the potential effects of reserve networks (Leslie and others 2003; Roberts and others 2003). Technical advice on establishing networks of marine and coastal protected areas is also available as supporting material for the Convention on Biological Diversity which sets out four principles for MPA network design; representativeness, replication, viability and a precautionary approach.

A key role of networks is to protect ecological processes essential for ecosystem functioning, even in the face of changing conditions of both human and natural origin (Roberts and others 2003). Reasons for establishing MPA networks include the following (Roberts & Hawkins 2000):

- Isolated reserves have many benefits but will only be able to protect a limited fraction of marine biodiversity.
- Large numbers of marine species have open water dispersal phases and can potentially be transported long distances from where they were spawned.
- Individual reserves may be able to sustain self-recruiting populations of species that disperse short distances, but networks will be necessary to protect many of the species that disperse long-distances.
- Network designs enable replication of the representation of ecosystems/habitats within MPAs. This can to help maintain habitat quality, ecosystem dynamics and act as reservoirs for recruitment and recolonisation of surrounding areas.
- Networks can be used to prevent/mitigate impacts of individual reserves eg edge effects around closures, by buffering or managing effort.

As with individual MPAs, the goals and objectives of a MPA network can be diverse. In some cases the focus is conservation of biodiversity (eg The OSPAR network – see Box 2). In other instances there may be a desire to build MPA networks to fulfil common goals for different user groups such as recreational, fisheries and nature conservation interests.

BOX 2: The purpose and scope of the OSPAR Network of MPAs

- Protect, conserve and restore species habitats and ecological processes which have been adversely affected by human activities.
- Prevent degradation of, and damage to, species, habitats and ecological processes, following the precautionary principle.
- Protect and conserve areas that best represent the range of species, habitats and ecological processes in the maritime area.

In many countries MPAs have evolved in response to a variety of demands rather than by systematic efforts to establish networks (Anon 2001). These include socio-political factors, the location of endangered or threatened species/habitats and attractive recreational locations. The Great Barrier Reef Marine Park (GBRMP) (see Box 3) is an exception.

BOX 3: Protected area networks in the Great Barrier Reef Marine Park.

In the late 1990s it was recognised that the existing zoning of the GBRMP did not protect the range of biodiversity known to exist in the MPA[1]. A network of no-take zones was considered to be a critical part of the solution to ensuring that the GBRMP remains healthy. Representative habitat types were mapped, the biological and physical diversity of the MPA was described, and the MPA was classified into bioregions. A combination of expert opinions, analytical approaches and stakeholder involvement were then used to identify options for a network of no-take zones in all the representative habitat types.

The Representative Areas Programme led to a new zoning plan for the entire Marine Park which came into effect in July 2004. This improved protection across the Marine Park and increased the number and extent of highly protected zones from 4.5% to over 33% (ie >115,000km^2) creating the world's largest network of HPMRs[2].

The marine SACs and SPAs which have been designated by Member States of the EU are often referred to as a network but are in fact a series of sites with no ecological connectivity between them.

Modern approaches to MPA design emphasise the need for networks for biodiversity conservation but they may also be designed to serve multiple purposes such as biodiversity conservation, ecosystem/habitat protection, fisheries enhancement and management and protection against periodic impacts (resilience). The protection of 'core' examples of ecosystems within multiple-use MPAs has been applied by a number of countries for biodiversity conservation with the Great Barrier Reef Marine Park one such example. There is however no standard, recommended size for MPAs in a network and various modelling packages have been developed which aim to 'optimise' network designs by providing different network configuration options.

3 Effects of Marine Protected Areas

There is a considerable and growing body of scientific literature on MPAs (eg Dugan & Davis 1993; Roberts & Hawkins 2000; Roberts & Polunin 1991; Halpern 2003). This includes more than two hundred recent studies on the effects of MPAs published in the peer reviewed primary literature between 1990 and 2001 (Willis and others 2003). This report reviews the scientific evidence supporting different views on the effects of MPAs, specifically in relation to the protection of marine biodiversity.

Both mathematical models and field studies have been used to evaluate the effects of MPAs, but it is important to note the limitations of each tool. Modelling is a simplified version of reality and the outcomes are driven by model assumptions. In the case of field studies, difficulties with the experimental design which need to be overcome include the absence of baseline information to enable direct comparisons with conditions before MPA management

[1] http://www.gbrmpa.gov.au/corp_site/key_issues/conservation/rep_areas/rep_area_overview.html [Accessed February 2006]
[2] http://www.gbrmpa.gov.au/corp_site/info_services/publications/brochures/protecting_biodiversity/ [Accessed February 2006]

was introduced, lack of control sites and limited opportunities for replication (temporally and spatially) to significantly assess their effects.

Other factors which influence the degree to which reserve effects are observed include design (size or location), the management regime (which can range from highly protected to multiple use), the effectiveness of enforcement, the baseline conditions, and how activities taking place outside the protected area are managed. Any effects also need to be set into the context of natural variability and global trends, such as those associated with climate change.

Working within these constraints, both positive and negative effects have been attributed to MPAs (see Table 2). There are also circumstances where no discernable effects have been observed or where there are insufficient data to take a view. A variety of effects may also be seen within a single MPA (see Box 4 & 5).

Table 2. Positive and negative effects attributed to MPAs.
Effects on marine biodiversity are shaded. (based on Anon 2001, Commonwealth of Australia 2003, Jones 2006)

Positive effects	Negative effects
● Protection of habitat ● Conservation of biodiversity ● Protection or enhancement of ecosystem services ● Recovery of depleted stocks of exploited species ● Export of individuals to fished areas ● Insurance against environmental or management uncertainty ● Scientific study ● Income generation (eg tourism, fishing) ● Education, training, culture and heritage ● Inspiration ● Raising profile of an area	* Increased pressure/impact on biodiversity by attracting certain activities, eg recreation * Increased pressure/impact on biodiversity outside the protected area due to displacement of activities * Loss of opportunities for exploitation within MPA * Exclusion of certain activities/uses from MPA * Income loss from closures

Box 4. Evaluating the effectiveness of marine protected areas: Multiple use area case study (GBRMPA 2003, 2005)

Site Name: The Great Barrier Reef Marine Park, Queensland, Australia

Site Description: A 345,000 km^2 reserve established in 1975 with management provisions introduced via zoning and management plans over the next 15 years. 16,000 km^2 of the MPA were made Highly Protected Marine Reserves in 2004 following publication of the 2003 Marine Zoning Plan. Principal habitats coral reefs, sandy cays, continental islands, algal and sponge gardens, mangrove estuaries, seagrass beds, sandy and muddy seabed communities.

Objectives as set out in Great Barrier Reef Marine Park Act, 1975

(a) **Conservation** of the GBR
(b) Regulation of the use of the Marine Park so as to protect the GBR while **allowing the reasonable use** of the GBR Region
(a) The regulation of activities that exploit the resources of the GBR Region so as to **minimise the effect of those activities** on the GBR
(b) The reservation of some areas of the GBR for its **appreciation and enjoyment** by the public
(c) The preservation of some areas of the GBR in its natural state undisturbed by man except for the purposes of scientific research

Box 4 contd

Management type: Multiple Use, IUCN Category VI

The GBRMP is a multiple-use MPA, allowing a range of ecologically sustainable uses with an overriding conservation objective; most reasonable activities are permitted, but zoned and regulated to minimise impacts, and separate incompatible activities in space and/or time. The spectrum of protection include general use areas which allow commercial and recreational activities that include fishing, collecting and trawling, to no-take areas that allow access but prohibit all extractive activities and preservation areas that prohibit all forms of access. A multitude of management tools (eg zoning, education, permits, management plans) are being used to help achieve ecological and other management objectives.

Current status/reserve effects with reference to the goals of the GBR Marine Park Authority

Goal	Outcome	Key indicators	Current Status
Protection	Conservation of biodiversity	Relative number of reefs that are 'healthy' compared to 'not healthy	Trends in coral cover are varied, but some reefs continue to exhibit more subtle indications of decline that are cause for concern. Some reefs, particularly inshore are considered 'at risk' from factors such as land based pollutant runoff.
	Improved water quality	Trends in chlorophyll *a* concentration	Significant differences between chlorophyll *a* levels near the coast and in the lagoon are evident in the central and southern regions of the GBRMP. Inshore concentrations of chlorophyll *a* are similar to offshore concentrations in the northern section of the GBR. The high concentrations of chlorophyll *a* in offshore waters in the southern GBR are related to the natural upwelling of deep sea nutrients.
Wise use	Sustainable fisheries	Proportion of fisheries with management plans and that comply with the Commonwealth's guidelines for ecologically sustainable fisheries	Eight of the eleven fisheries assessed are consistent with the *Environment Protection and Biodiversity Conservation Act 1999* and are not likely to have an unacceptable impact in the short-term. A further three are being managed in an ecologically sustainable way, in accordance with Guidelines. Assessment is in progress for four other fisheries.
	Effective park management	The number of bioregions with adequate 'No-Take Zones'	The number of protected areas has increased since the establishment of the GBRMP in 1975. With the launch of the *Great Barrier Reef Marine Park Zoning Plan 2003*, the number of bioregions afforded adequate protection has increased to 70, encompassing all the recognised bioregions in the GBRMP
	Accurate and adequate information available for management	Number of technical & scientific publications published about the GBR by the Authority and the CRC	The number of publications released by the GBRMPA and Reef Cooperative Research Centre (CRC) has increased steadily over the years. Actual numbers vary from year to year. Information sheets and pamphlets are also published on a regular basis.
Understanding and enjoyment		Trends in the number of tourists to the GBRMP and their satisfaction with their experience	Annual number of visitors to the Park has increased steadily since 1993. 2005 survey of people from Great Barrier Reef coastal communities and major Australian capital cities, reported that 80% of respondents who visited the Marine Park in 2004-05 were either very satisfied or satisfied with their recent trip.
	Improved community understanding of the GBRMP	Public understanding of the main threats to the GBR is increasing.	Regular surveys are carried out where respondents were asked the likelihood of specific activities having an impact on the Reef. Declining water quality is currently one of the major threats to the GBR and the 2005 survey demonstrated respondents understanding of the degree of threat from specific elements that directly relate to water quality.

Box 5. Evaluating the effectiveness of marine protected areas: Highly protected marine reserve case study (McArdle 1997; Parnell and others 2005)

Site Name: The San Diego – La Jolla Ecological Reserve, California, USA

Site Description: A small 2.16 km^2 reserve established in 1971, Principal habitats are kelp forest, boulder reef, sandstone cliffs and promontories, and gently sloping sandy shelf.

Goals of Ecological Reserves in California: To protect threatened and endangered native plants, wildlife or aquatic organisms, or specialised habitat types, both terrestrial and aquatic, or large heterogeneous natural gene pools for the future of mankind.

Management type: Highly Protected Marine Reserve, IUCN Category I

- All recreational fishing prohibited;
- Commercial fishing prohibited except bait fishing for squid using hand-held scoop nets;
- Kelp harvesting prohibited;
- No disturbance of geological formations or archaeological artefacts; and
- No taking or disturbing any birds or nests, or eggs thereof, or any plant, mammal, crustacean, amphibian, reptile or any other form of plant or animal life.

Statistically significant positive reserve effects

Kelp habitat [Figures A & B]

- Inside/outside comparisons of seven targeted animals in the kelp habitat showed significantly higher densities of red urchins, rock scallops, and male and female sheephead in the reserve.
- A significantly larger proportion of male >50cm sheephead inside the reserve. Male sheephead this size are at least 10-20yrs old and rarely observed outside the reserve.
- A larger (but non-significant) proportion of female sheephead >25cm in the reserve.
- Population of adult red urchins significantly larger inside the reserve.

Green abalones in boulder reef habitat

- Densities of green abalone significantly greater inside the reserve
- Average density of large green abalone within the reserve larger by a factor of around 2
- Green abalone significantly more likely to be found in aggregations inside the reserve (68% inside the reserve). This species is effectively sterile if they do not aggregate in groups of mixed sexes.
- Aggregations of green abalone inside the reserve were all composed of large individuals

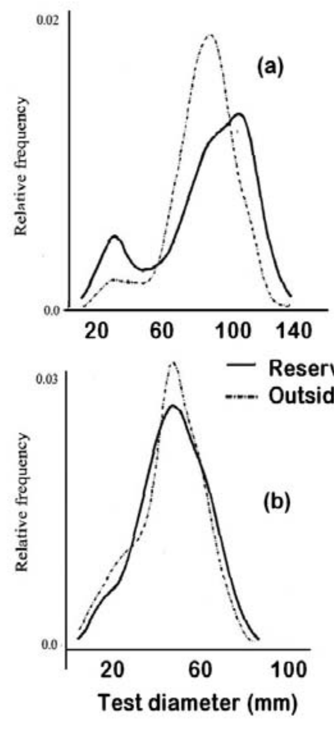
Canyon habitat

- Relative abundance of vermillion rock fish and sheephead significantly greater within the reserve.

Qualitative observations of reserve effects

- Several very large lobsters observed in the boulder reef habitat. Individuals of this size are very rarely observed therefore the reserve may be protecting some resident lobsters. Further evidence of this is the observation that lobster traps are still common on the western margin of the reserve late in the lobster season but have disappeared from the rest of San Diego, indicating there is spill over.

FIGURE A. Red urchin (a) and purple urchin (b) size frequency distributions inside and outside reserve.



(Parnell and others 2005)

BOX 5 (contd)

- Male sheephead are important predators of urchins and are therefore capable of indirectly affecting kelp densities through a trophic cascade. The reserve provides important conservation protection for large male sheephead and the trophic structure within the reserve therefore probably reflects a more natural condition than that outside.
- Given the long larval planktonic period of the urchin, the reserve is probably not self-sustaining for red urchins.

Statistically significant negative reserve effects
None

Absence of significant reserve effects
Kelp habitat

- Kelp bass size frequency similar inside and outside the reserve. The reserve is not likely to be effective for this species because its boundary crosses the middle of the kelp forest, and it has a range far larger than the area of the kelp forest inside the reserve.
- The reserve offers little protection for sculpin. This species is subject to fishing outside the reserve, can migrate kilometres to spawn. It cannot be protected by the small reserve although the reserve could offer important protection for spawning aggregations.
- There was no significant difference in the size frequency of purple sea urchin inside and outside the reserve. Unlike the red sea urchin (where a difference was observed) this species is not subject to fishing pressure.

Conclusions from evaluation study

- The reserve appears to protect only a few harvested species, those that are sessile or highly residential; this suggests (enforcement issues aside) that the reserve is too small.
- Comparisons with historical data indicate that most harvest species in the reserve (including some where there was a positive reserve effect) have declined seriously since 1979. This indicates that the magnitude of any reserve effect is inadequate to protect most species from natural and anthropogenic perturbations, further supporting the contention that the reserve is too small
- The reserve may function as an enhancive reserve for green abalone in the boulder-reef habitat, red urchins in the kelp habitat, and vermilion rockfish and sheephead in the canyon habitat, since large individual of these species were observed in higher densities inside the reserve that outside.

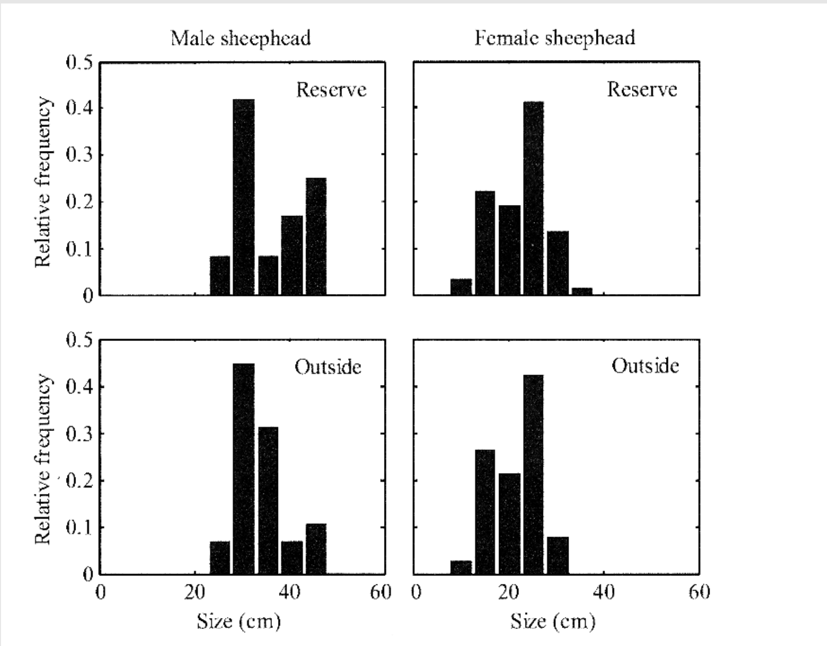


FIGURE B. Size frequency distribution of male and female sheephead inside and outside reserve in similar habitats.

(Parnell and others 2005)

3.1 Positive effects on marine biodiversity attributed to Marine Protected Areas

A great deal has been written about the potential benefits of MPAs (Commonwealth of Australia 2003). Direct evidence is available from existing sites, with positive effects reported from nearly all of the field studies described in 200 scientific papers published between 1990 and 2001 (Willis and others 2003). The scientific evidence of marine biodiversity benefits is presented below using examples from around the world, but with an emphasis on temperate regions, due to their relevance to UK waters.

3.1.1 Conservation of biodiversity

The UK Government report on the 'State of UK Seas' (Defra 2005b) has concluded that "human activity has already resulted in adverse changes to marine life and continues to do so". Numerous scientific papers and reviews present evidence of how MPAs can benefit marine biodiversity to reverse observed trends (eg Anon 2001; Gell & Roberts 2005; IMPAC 1 2005; Lubchenco and others 2003).

A recent evaluation of data from field studies into the effect of Highly Protected Marine Reserves (HPMRs) on biological measures revealed overwhelmingly positive effects (Halpern 2003). This was based on 89 studies that made 112 independent measures of the effects of HPMRs. Eighty-one of these were used for qualitative analyses and 69 for quantitative analysis. The effects were apparent as higher density, biomass, organism size and diversity of four functional groups; herbivores, planktivore/invertebrate eaters, carnivores and invertebrates. In most cases these values were higher within the reserves compared to outside, or after reserve establishment compared to before (Figure 1).

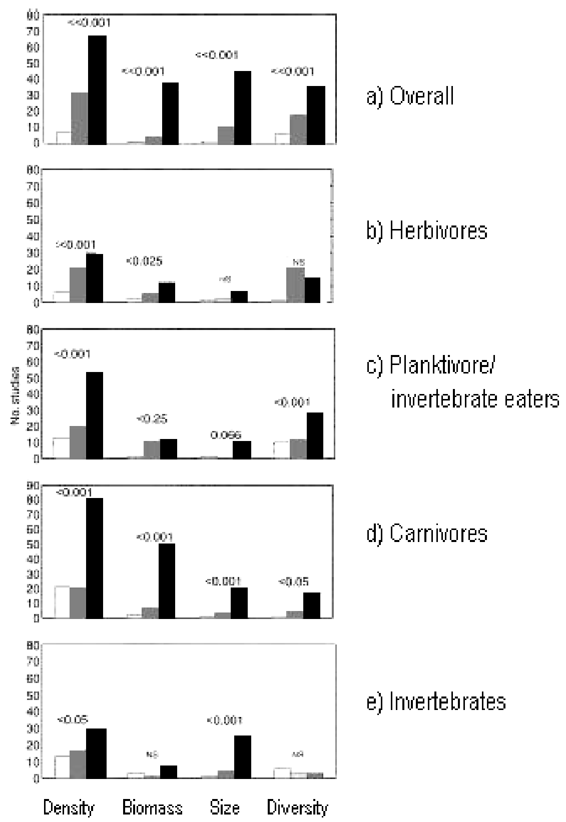


Figure 1

Differences in biological measures between inside a reserve and outside (or after vs.before) for all organisms (a) and for each functional group (b-e).

White bars represent lower values inside the reserve, grey represent no differences between reserve and non reserve areas and black bars represent higher values inside the reserve. P values above the bars are significance for chi-square test values (Halpern 2003).

The diversity of communities and the mean size of the organisms within the HPMRs examined in this study were between 20-30% higher relative to unprotected areas. The density of organisms was roughly double in reserves, while the biomass of organisms was nearly triple. In all but one case, the effect was independent of reserve size.

The following examples give details of some of the positive effects which HPMRs have had on marine biodiversity;

- Tasmania, Maria island – densities of rock lobster and bastard trumpeter fish increased by 1 and 2 orders of magnitude respectively within the reserve. Number of species of fish, inverts and algae also increased as did fish larger than 33cm (Edgar & Barrett 1999).
- UK, Lundy Island No-Take Zone – the abundance of lobsters was significantly greater inside than outside the NTZ in both near and far field control sites within the first year of establishment of a HPMR (Figure 2). Lobster numbers increased by 76 % within the HPMR and there were three times as many above the minimum landing size when compared to control sites outside the HPMR (Hoskin and others 2005).

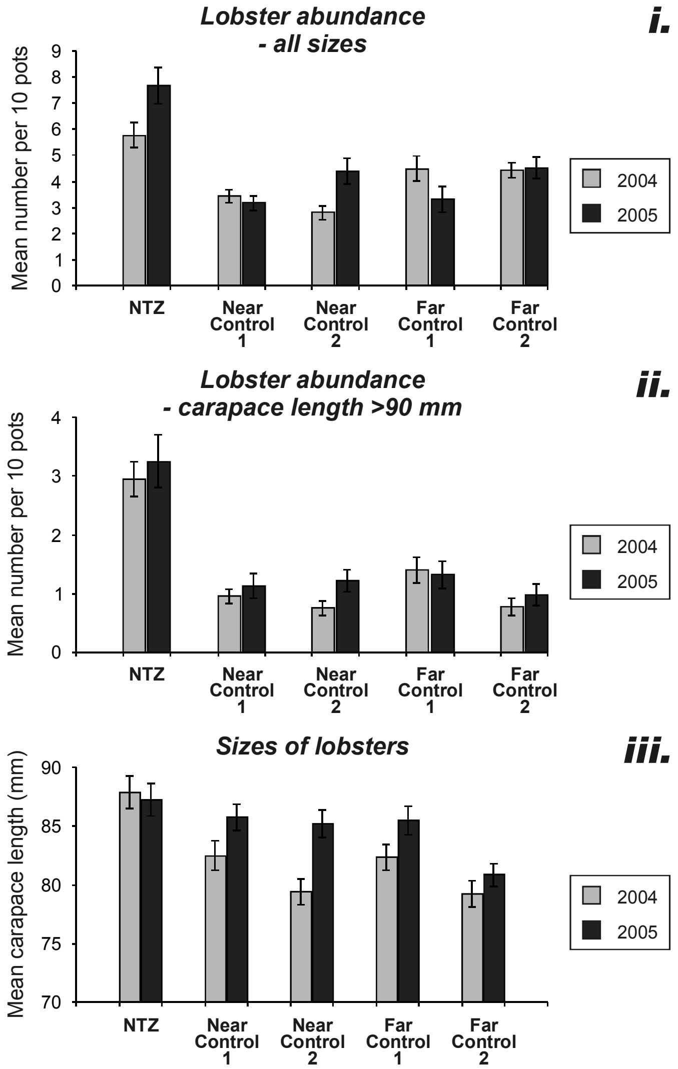


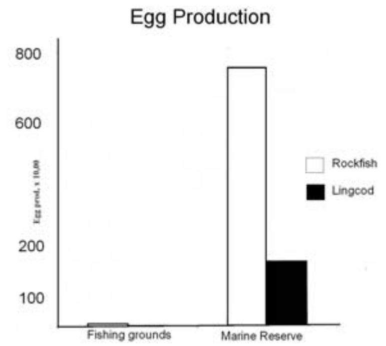
Figure 2.

Lobster, *Homarus gammarus* variation in the Lundy NTZ.

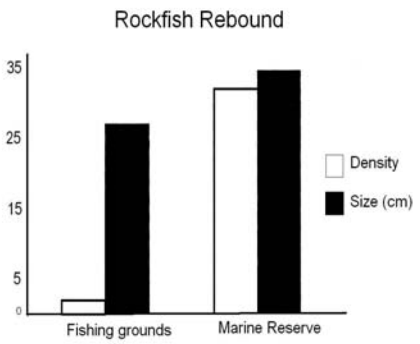
Near control and far control locations in 2004 & 2005 for (i) mean abundance of lobsters of all sizes (ii) mean abundances lobsters of landable size (carapace length >90mm) (iii) mean carapace length of lobsters.

(Hoskin and others 2005)

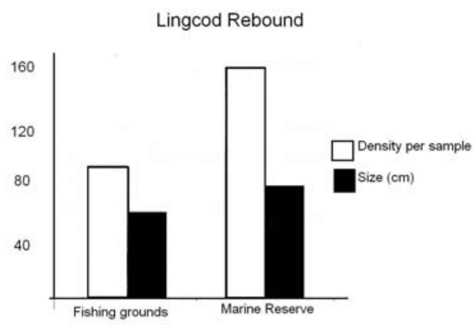
- New Zealand, Leigh – the predatory fish *Pagrus auratus* was 6 times more common in the reserve than outside and the spiny lobster *Jasus edwards* 1.6 times more abundant and had a bigger carapace size. Sea urchin densities in the reserve declined in the reserve (possibly due to the increase in more predatory fish) while rising in unprotected areas (Babcock and others 1999).
- New Zealand, Tawharanui - the predatory fish *Pagrus auratus* was 9 times more common in the reserve than outside and the spiny lobster *Jasus edwards* 3.7 times more abundant and had a bigger carapace size. (Babcock and others 1999).
- New Zealand, Leigh & Tawharanui – since reserve establishment densities of sea urchins have declined following increases in the abundance of the most common demersal predatory fish (see above). As a result urchin-dominated barrens occupied only 14% of available reef substratum in the reserve as opposed to 40% in unprotected areas. Consequently kelp forests were more extensive that when the reserves were created.
- USA, Shady Cove – lingcod were nearly three times more abundant in the reserve as were lingcod nests (Palsson & Pacunski, 1995). (Figure 3)
- USA, Edmonds Underwater Park – the number of rockfish eggs and larvae origination from within the park were 55 times greater than outside and 20 times greater for (Palsson & Pacunski, 1995) (Figure 3)



(i)



(ii)



(iii)

Figure 3. Reserve effects on ling cod and rockfish in the Shady Cove and Edmonds Underwater Parks compared to fishing ground control sites.
(i) Estimated egg production of rockfish and lingcod in the Edmunds Underwater Park.
(ii) Density and size of copper rockfish in Edmunds Underwater Park
(iii) Density and size of lingcod in the Shady Cove Marine Reserve

- South Africa, Tsitsikamma Coastal National Park,– abundance and distribution of three species of temperate reef fish in this unexploited area were compared to a similar site off Cape Recife where fishing is permitted. In all cases the fish were significantly more abundant in the MPA. There were also more in larger size classes and the maximum size of fish was greater inside the reserve (Buxton & Smale 1989).
- Spain, Tarbaca – following protection from collection, densities of the fan shell *Pinna nobilis* became twelve times higher in the MPA than in nearby areas where collection could continue (Ramos & McNeil 1994).

MPAs are also known to have affected marine communities. Prohibiting the collection of marine life from a rocky shore at Punta El Lacho in Chile, led to a change from communities dominated by mussels to one dominated by barnacles. This shift is believed to be a result of recovery of loco (*Concholepas concholepas*) a predatory snail which had been overexploited before protection in a multiple-use MPA (Castilla & Duran 1985).

In New Zealand protection has caused cascading effects on local food webs where increases in previously fished predators (snapper and lobster) have resulted in localised declines of their herbivorous prey (sea urchins) and subsequent increases in kelp production. The changes in community structure have persisted since at least 1994, demonstrating higher tropic complexity and increased primary and secondary productivity in MPAs as a consequence of protection (Babcock and others 1999). This type of effect (trophic cascades) has also been reported from the Channel Islands National Parks, a multiple-use MPA, based on two decades of data (Salomon and others 2005).

The time scale over which effects become apparent can be difficult to predict. In some cases changes have been observed almost immediately and in others not at all or over very long time scales. In the Lundy Island NTZ there were significant differences in lobster abundance within the first year of establishment; differences in scallop abundance were not significant although scallops were significantly larger within the NTZ when compared to adjacent control areas two years after establishment. No significant differences were seen in the epifauna in these two years (Hoskin and others 2005).

In Start Bay, off the coast of south Devon, seasonally fished areas (a multiple-use MPA) were indistinguishable from regularly towed areas. Given that recruitment is needed from surrounding areas and the large scale of fishing operations, it has been suggested that it may take benthic species decades to recovery. Two years was certainly insufficient to allow recovery of benthic communities to a condition where they were indistinguishable from areas where only static gears had been deployed (Blyth and others 2004).

3.1.2 Habitat protection

The UK Government report on the 'State of UK Seas' (Defra 2005b) has concluded that "there are likely to be few areas of marine habitats in the UK which remain unchanged by human activities". The most widely reported changes are linked to the use of bottom fishing gears, aggregate dredging and the dumping of spoil. These can result in removal or smothering of the substrate, or direct physical damage (Boyd and others 2003; CEFAS 2003; Groot & Lindeboom 1994). Changes in water quality, currents, the sorting of sediments, and cumulative impacts might result in more subtle changes, such as a gradual deterioration in habitat quality (Holt and others 1998).

Reported direct habitat protection benefits of MPAs fall into two categories; preventing or reducing the impact of human activities, and providing conditions free from recurring impact thus allowing time and space for recovery and restoration. Wider effects such as supporting community structure and providing ecosystem services are described in section 3.1.3.

The view that excluding certain activities from MPAs can prevent or reduce the impact of human activities on seabed habitats is based on the considerable body of scientific evidence that human activities can have an impact on the seabed, with certain habitat types being more vulnerable than others (eg Kaiser & de Groot 2000).

- An investigation into the effects of different types of fisheries on the North Sea and Irish Sea showed that beam trawls and otter trawls leave detectable marks on the seafloor, flatten the contours on the sediment surface and suspend smaller sediment particles (Lindeboom & de Groot (1998). The suspended sediment can clog up the feeding and respiratory structures of suspension feeders such as sponges, sea firs and sea mats and if deposited on hard surfaces can affect the settlement of larvae of some species (OSPAR 1998). The longevity of these effects depends on local conditions, the sediment type and the intensity of the activity.
- The removal of aggregate can have both immediate and long term effects on the character of the seabed (ICES 1992). Anchor dredging changes the topography of the seabed while trailer dredger creates shallow furrows. In the UK sediment composition has been known to change from sandy gravel to gravely sand as a result of aggregate extraction (Boyd and others 2003). This, in turn, will affect the biological communities that can be supported by these habitats.
- The disposal of dredged material onto the seabed can change the nature of the seabed sediment and therefore the associated benthic communities. At the Rough Tower disposal site (outer Thames estuary) there has been a net coarsening of sediments at the disposal site as a result of recent and historical disposal activity (CEFAS 2003).
- Data from scallop dredging experiments on maerl beds in the Clyde Sea revealed differences between dredged and undredged areas. Closure of areas to commercial dredging in this study allowed the development of more heterogeneous benthic communities (Bradshaw and others 2001).

The evidence that MPAs can support recovery and restoration of degraded or damaged habitats comes from experimental and field studies showing that in some situations recovery to pre-impact conditions is possible:

- Following experimental cockle dredging of sandflats in the Burry Inlet, dredge tracks were visible in the surface sediments. These were still apparent six months later in one trial site where conditions were more stable, whereas there were no obvious differences from original conditions in the more dynamic site where sediments were more mobile (Rostron 1995).
- Suction dredging to harvest clams on a shallow shelving mudflat area in Whitstable, Kent removed the upper sediment layers exposing clay. Seven months later, natural sedimentation had nearly restored the sediment structure (Kaiser and others 1994).

- Monitoring of a number of aggregate extraction sites where activity as ceased has revealed some 'recovery' at two of the four study sites (the areas of lower dredging intensity) after eight years, albeit at a much slower rate than anticipated (Cooper and others 2005).
- Large scale investigations of scallop dredging on soft sediment communities in Port Phillip Bay, Australia, recorded physical changes to the surface of the seabed (pits, depressions and tracks) immediately after the dredging activity. No physical differences were apparent between dredged and control sites eleven months later (Currie & Parry 1996).
- Comparison of the relative abundance of microhabitat features inside and outside an area closed to fishing on the Georges Bank showed significant difference in the relative abundance of the shell fragment and sponge microhabitat types between fished and unfished areas. There were no significant differences in five other microhabitat types. The researchers believe that the lack of difference in the latter cases may indicate that the level of fishing activity in the area was matched by the ability of the system to recover (Lindholm, Auster & Valentine 2004).

The time taken for recovery depends on many factors such as the type of habitat, the degree of damage (ie habitat quality), the environmental conditions, the level of protection and design factors such as size, location, and role in a network of MPAs. In less dynamic conditions, or in the case of habitats created by long lived or slow growing species it may be many decades before a reserve effect is apparent. Two situations in the UK where this may be the case are mature horse mussel *Modiolus modiolus* beds as these mussels have a estimated life span of between 20-100 years (MarLin 2006) and maerl beds, formed by a calcified red seaweed, whose growth rate is estimated to be a few millimetres a year (Birkett and others 1988).

Evidence that MPAs could prevent more subtle deterioration of habitats is hard to find as the causes are often more diffuse (eg climate change, water quality changes, disease) and therefore difficult to quantify.

3.1.3 Benefits for commercially exploited species

Frequently discussed potential benefits of MPAs to commercial fisheries are the recovery of depleted stocks of exploited species and the dispersal of commercially valuable species out from an MPA to supplement surrounding fisheries (otherwise known as the 'spill over effect'). These subjects are considered in great detail in numerous scientific papers and reviews (eg Dugan & Davis 1993: Gell & Roberts 2003; Sweeting & Polunin 2005; Beukers-Stewart and others 2005).

The role of MPAs as a fisheries management tool is not discussed in this report however commercial species are an intrinsic part of the ecosystem and some of these species and fish stocks, can benefit from MPAs even where the principal objective is biodiversity conservation rather than fisheries management. Examples of such positive reserve effects are given below:

- USA, Merritt Island National Wildlife Refuge - experimental fishing within the reserve after 24 and 28 years closure revealed more abundant and larger target species than outside the reserve. Tagged fish moved from the HPMR to fished areas. An effect attributed to spill over from the HPMR is the much higher percentage of world record size fish of three target species being caught in the vicinity of the HPMR than further afield (Johnson, Funicelli & Bohnsack 1999; Roberts and others 2001).
- South Africa, De Hoop Marine Reserve - catch per unit effort increased by up to five fold for 6 out of 10 of the most commercially important species in this warm temperate rocky reef MPA (Bennett & Attwood 1991).
- USA, Channel Islands - densities of the commercially exploited red sea urchin were nine times higher in the reserve that in nearby fished areas (Fugita, Willingham & Freitas 1998).
- New Zealand, Leigh Marine Reserve – densities of fishable size individuals of an exploited bream were 5.8 – 8.7 times higher in the reserve compared to fished areas nearby by. Spiny lobster densities were approximately 5 times higher than in the fished areas (Babcock and others 1999; Kelly and others 2000).
- France, Banyuls-Cerbere Marine Reserve, France – A comparison of the density of two species targeted by spearfishermen showed they were significantly more abundant inside than outside the reserve. *Dicentrarchus labrax* was nearly six times more abundant and had a mean length nearly 80% greater in the protected area than in the unprotected area and the bream more than 13 times more abundant but with no significant differences in mean length (Jouvenel & Pollard 2001).
- Australia, Great Barrier Reef Marine Park, – quantitative estimates of the density and biomass of coral trout *Plectropomus* spp, the major target of hook and line fisheries on the reef 3-4 years before and 12-13 years after the establishment of HPMR within the Marine Park. Density and biomass increased significantly (by factors between 4 -6.3 depending on location) in the protected areas but not in the fished sites. The density and biomass of non-target fish species did not differ significantly (Williamson and others 2005).

3.1.4 Protection & enhancement of ecosystem services

MPAs set up to protect marine wildlife and habitats have biodiversity goals and targets but with growing support for an ecosystem based approach to management, there is also interest in how MPAs might help to protect and enhance ‘ecosystem services’.

Ecosystem services include flood and storm protection, nutrient cycling, and the maintenance of water quality (Box 6). They operate on a variety of scales, from global to local, and are usually difficult to quantify although there are some examples where this has been done (eg sand production from coral reefs in the Great Barrier Reef Marine Park, coast protection value of saltmarshes).

Box 6. Coastal and marine ecosystem services

- shoreline maintenance
- flood and storm protection
- sand production
- nutrient cycling
- waste assimilation and remediation
- water quality maintenance
- habitat
- maintenance of biodiversity
- maintenance of biological resilience
- mixing and transport of organic production to food webs
- development and transport of larvae and young
- wave and tidal energy
- recreation
- inspiration and support of cultural, aesthetic and spiritual values

(Commonwealth of Australia 2003)

The most direct evidence that MPAs can protect and enhance ecosystem services comes from situations where such services are linked to habitats and species which MPAs are established to protect.

Temperate water examples provided below are based on referenced text from the marine biotopes reports prepared as part of the UK Marine SACs project[3] and the Marine Life Information Network (MarLIN) [4].

Seagrass habitats

Subtidal seagrass beds (Davison & Hughes 1998) are considered to be the most productive of shallow, sedimentary environments. Ecosystem services include supporting a rich, resident fauna, being used as refuge and nursery areas, supporting detritus-based food chains within and beyond the seagrass bed, increasing rates of sedimentation, and binding the substratum together, thereby reducing sediment erosion, as well as oxygenating the sediment.

Algal habitats

Kelp forests (Birkett, Maggs & Dring 1998) are the marine equivalent of tropical rain forests in terms of their biological diversity, productivity, population inhabiting or dependent on the habitat. Ninety percent of kelp production is estimated to enter the detrital food webs of coastal areas supporting habitats beyond the kelp beds such as benthic communities. Kelp beds in shallow waters also have a physical role, dampening the force of the waves arriving at the shore.

Maerl beds (Birkett, Maggs & Dring 1998) provide valuable habitat for other species as a surface for attachment and within the loose structure. Many coralline algae produce chemicals which promote the settlement of the larvae of certain herbivorous invertebrate. Maerl is also one of the sources of subtidal and beach-forming calcareous sediments (up to 4% of calcareous sediments in Scotland). There is good evidence that maerl beds are nurseries for some species eg juvenile cod, saithe and pollack (Kamenos, Moore & Hall-

[3] http://www.ukmarinesac.org.uk [Accessed February 2006]
[4] http://www.marlin.ac.uk [Accessed February 2006]

Spencer 2004a) and invertebrates such as the queen scallop *Aequipecten opercularis*, soft clam *Mya arenaria* and sea urchins *Psammechinus miliaris* and *Echinus esculentus* (Kamenos, Moore & Hall-Spencer 2004b).

Biogenic reefs

Blue mussel beds (*Mytilus edulis*) are extremely important in the generation of organically enriched biodeposits that provide nutrition for wide ranges of deposit feeding invertebrates not just within them but over wide areas of tidal flats around them (Holt and others 1998). *Mytilus* in reefs and beds are a very important food source for some species of bird, and in some bays mussel beds are of a such a scale that by their filter feeding they play a particularly important role in energy flow over much wider areas than the actual beds. Mussel beds result in significant depletion of phytoplankton at the bottom of the water column and function as systems, not just as populations of mussels (Asmus & Asmus 1991; Frechette & Grant 1991). Blue mussels have a strong stabilising effect on sediment, for periods varying from a few months to many years, and it has been suggested that in their absence large scale changes to whole estuary complexes may occur (McKay 1998).

Horse Mussel *Modiolus modiolus* reefs (Tyler-Walters 2001) can be very extensive, and often include many other filter feeders (eg. sponges, hydroids, bryozoans, soft corals, brittlestars, bivalves and ascidians) and therefore are probably of great importance in channelling organic material between the plankton and the benthos. A study in Newfoundland quantified the role of *Modiolus modiolus* beds in cycling nutrient to the benthic ecosystem. The horse mussels fed on small phytoplankton but concentrated large diatoms in their pseudofaeces, contributing up to 40.9 mg dry weight per individual per day (Navarro & Thompson 1997). In the Bay of Fundy horse mussel beds were able to feed on phytoplankton down to about 100m in depth and were the largest contributor to secondary benthic productivity (Wildish & Fader 1998).

Sediment megafauna

The activities of large sediment burrowing animals (megafauna) can have a profound influence on their environment (Hughes 1998). In the southern North Sea, *Callianassa subterranea* was estimated to turn over a total of 11 kg/m^2/yr dry sediment while in an Adriatic lagoon, the volume of water pumped through burrows by *Upogebia pusilla* during periods of neap tides almost equalled the inflow of water from the open sea. By constructing and ventilating burrows, megafauna oxygenate the sediments and make them less compact. This allows smaller animals (macrofauna) to occupy otherwise uninhabitable deeper sediments and may locally enhance the food supply by stimulating bacterial growth. Negative effects of burrowing megafauna on macrofaunal populations may arise directly by predation, or indirectly as a result of burial, increased turbidity or sediment compaction.

3.1.5 Insurance against environmental or management uncertainty

The potential for MPAs to act as insurance against environmental or management uncertainty is being promoted as a biodiversity conservation benefit by a number of countries:

- In Australia the recent rezoning of the Great Barrier Reef Marine Park to include 20% of each of the 70 bioregions as a ‘Green Zone’ (a Highly Protected Marine Reserve) is intended to enhance the resilience of the natural system to cope with global scale change.

- In Canada, the Federal Marine Protected Areas Strategy states that establishing networks of MPAs may be used to reduce the effects of localised human or natural catastrophes.

Replication within networks of MPAs can be an insurance policy but this role is also written into the objectives for individual MPAs. For example the objectives of the Monterey Bay National Marine Sanctuary include providing, ecological 'insurance' against environmental variability and unintentional mis-managment. Whether this can be achieved is still to be tested.

3.1.6 Sites for scientific investigation and education

MPAs have been used as a source of baseline data acting as control areas to determine the effects of activities taking place outside MPAs. This is especially the case in HPMRs where the goal may be to act as reference sites for monitoring impacts of human activities. MPAs have also provided opportunities for other types of research, for example into the ecology of marine communities or particular species, where human activities operate within a known framework of management.

Around the Isle of Man, populations of scallops within and outside a MPA which is closed to commercial fishing with mobile gear have been studied for 14 years (Beukers-Steward and others 2005). Although low in both areas to start with the densities increased at an accelerated rate within the closed area. Densities were more than 7 times higher in the closed area by 2003 and with exploitable biomass, eleven times higher and reproductive biomass 12.5 times higher. Juvenile scallops also had a higher growth rate and survival in the undisturbed environment. The researchers concluded that fisheries for relatively sedentary and long –lived species such as *Pecten maximus* would benefit from this type of management regime.

The consequences of changes in single components of systems (such as removal of high level predators) elsewhere in the same system are difficult to determine. One way is by examining changes in the food webs also known as ‘trophic cascades’. Where MPAs represent unexploited systems they have been used to investigate such effects by providing reference areas. A review of 30 documented cases from around the world used MPAs as part of the study. They revealed, for example that the expansion of coralline barrens in the Mediterranean rocky sublittoral will not be readily reversed in MPAs, probably because factors other than predation-based cascades have contributed to them in the first place.

There are many examples of MPAs with marine education programmes. They have been used to support both formal education and informal education through the dissemination of information, provision educational materials, field-based education officers and interpretive centres. Educational activities such as rockpool rambles and low tide days with coastal wardens provide opportunities for learning in the field while the involvement of users in developing coastal codes for activities within MPAs are opportunities to learn about conservation management issues and develop practical ways forward. The UK Marine SACs LIFE Project and work at some of the project locations illustrate what can be done (English Nature and others 2001). They can also act as a catalyst for MPA managers to gain a better understanding of local issues from local knowledge. The participatory workshops held to draw up the management schemes for the North East Kent European marine site is a good example of this.

3.2 Mixed, negative or no discernable effects on biodiversity attributed to Marine Protected Areas

Not all studies into the effects of individual MPAs reveal positive effects on marine biodiversity. In some cases the results are mixed, or there may be no discernable effects. In others, negative effects on surrounding areas have been reported. Where reasons are given they are typically concerned with the design and management of the MPA (See Box 7).

Box. 7

Example of reasons for failures of fisheries MPAs which are also relevant to MPAs with biodiversity conservation objectives (Baker 2000).

Initial degraded conditions
Far field effects (eg poor water quality)
Poor location (eg marginal habitat for target species)
Inappropriate design (eg insufficient size)
Natural variability (eg poor recruitment years)
Breaches of management regulations

Example of reasons for MPAs failing to achieve their management objectives (Kelleher, Bleakley & Wells 1995)

- Insufficient financial and technical resources to develop and implement management plans and lack of trained staff.
- Lack of data for management decisions, including information on the impacts of resource use and on the status of biological resources.
- Lack of public support and unwillingness of users to follow management rules, often because users have not been involved in establishing such rules.
- Inadequate commitment to enforcing management.
- Unsustainable use of resources occurring within MPAs.
- Impacts from activities in land and sea areas outside the boundaries of MPAs, including pollution and overexploitation.
- Lack of clear organisational responsibilities for management and absence of coordination between agencies with responsibilities relevant to MPAs.

- A long-term study of a HPMR in Tasmania indicated that fishing had had a substantial influence on the demographic structure of a number of species. After protection, not all species increased in size and/or abundance and for some fish species no significant change was detected. The restricted movement of most of the species studies suggested limited spill over. The overall results however suggest that even relatively small MPAs can effectively achieve local conservation objectives, especially for resident or sedentary exploited species (Haddon and others 2005). The mobility of the species and its range in relation to the boundaries of the protected area is therefore an important influence on any reserve effect.
- The Galapagos Marine Reserve is a multiple-use MPA. There is a complex management framework and zoning schemes, closed seasons and quotas. Despite this the sea cucumber fishery is showing clear signs of severe depletion and the lobster fishery has shown some

systemic declines. Changes in the management regime as well as better enforcement and linkage between the no-take zones and the wider zoning scheme have been recommended to address the problem (Hearn and others 2005).

- At the South Lagoon Marine Park, New Caledonia the species richness of fish populations increased by 67%, density by 160% and biomass by 246% following protection, but the average size of most species did not increase (Wantiez, Thollot & Kulbicki 1997).
- The Florida Keys National Marine Sanctuary has had twenty three small HPMRs since 1997. There is ongoing research into the effects on heavily exploited fishes and invertebrates, benthic communities and human activities. Preliminary reports indicate increases within fully protected marine zones in the number and size of heavily exploited species such as spiny lobster and certain reef fishes. Slower-growing benthic species such as corals and sponges have not shown significant changes. No strong negative socioeconomic impacts of zoning have been detected (Keller 2005).
- There were mixed results from an evaluation of the effects of marine reserves on temperate kelp forest systems in central California (US Department of Commerce 2004). Densities of fishes were 12-35% greater within the reserves but this difference was not statistically significant. Habitat features explained only 4% of the variation in fish density and did not vary consistently between reserves and non-reserves. The average length of rockfish (genus *Sebastes*) was significantly greater in 2 of the 3 reserve sites, as was the proportion of larger fish. Population density and size differences combined to produce substantially greater biomass and therefore reproductive potential per unit of area within the reserves. The magnitude of these effects seems to be influenced by the reserve age and the differences between the reserves and adjacent non-reserves were considered to be surprisingly small. Potentially confounding influences include the very small size of the reserves, effects of historical fishing, poaching, spill over effects on adult and larval populations from reserve to non-reserve habitats, and the possibility that catastrophic phase shifts induced by human disturbances have altered both reserve and non-reserve areas[5].

Negative effects may result from attracting activities into an MPA. Whale watching, if not carried out responsibly is one example. MPAs established in areas important for cetaceans can attract many thousands of visitors and there is a danger that the resulting whale watching activities may harass, disturb or injure cetaceans. On the other hand the management regime of an MPA provides an ideal framework for introducing whale watching codes, surveillance and penalties for infringement (Hoyt 2005).

Most reported negative effects of MPAs on marine biodiversity are usually outside the MPA and a consequence of the displacement of fishing activities which used to take place within the MPA.

Modelling of a closure of the UK sole fishery around Trevose Bank shows a negligible advantage if the displaced effort put pressure on the stock elsewhere (Horwood, Nichols and Milligan 1998). An assessment of the effects of the North Sea plaice box, a partial closure, reported strong evidence of increase in the relative abundance of marketable plaice and a small increase in the recruitment of sole (ICES 1994). Modelling suggested removal of the box would result in declines in the Spawning Stock Biomass and yield. The introduction of

[5] http://www.sanctuaries.nos.noaa.gov/science/conservation/starr1.html [Accessed February 2006]

the box did however change the pattern of fishing of different fleets. One of these was increased effort around the edges of the box which offset some of the benefits. There was also exploitation of other fisheries inside the box and coincident widespread changes in the south-eastern North Sea ecosystem which made it difficult to determine the precise effects of the plaice box (Sweeting and Polunin 2005). This example not only illustrates the complexity of measuring reserve effects but also the importance of examining effects in a wider context.

No MPA exists in isolation and these cases demonstrate problems with the wider management regime rather than failure of the MPA and highlight the importance of MPAs being set into a wider sustainable marine management context rather than isolated islands of biodiversity conservation.

4 Summary and conclusions

Marine Protected Areas are an established part of marine conservation programmes around the world. In the UK, most MPAs are 'European marine sites' (Special Areas of Conservation or Special Protection Areas as defined by the EU Birds and Habitats Directives). There are also a small number of 'Marine Nature Reserves', 'voluntary marine conservation areas' and Sites of Special Scientific Interest which extend into intertidal and subtidal areas.

The UK is committed to identifying and designating relevant areas of the UK's seas as areas of marine protection belonging to "a network of well-managed sites by 2010" As part of this, the Government is also considering what role MPAs can play in ensuring functioning and resilient ecosystems and the protection of biodiversity.

Conservation of biological diversity and productivity are the main reasons for establishing many MPAs but these are rarely the only reasons. MPAs may also have research, social and economic goals and objectives, as well as objectives concerned with the setting up and effective management of the protected area. In more recent years objectives such as these are also being sought through the establishment of networks of MPAs (a collection of individual sites that are connected in some way by ecological or other processes).

This report has examined the evidence for reserve effects in MPAs set up for the conservation of marine biodiversity and across the full spectrum of management regimes from HPMRs to multiple-use management areas. MPAs with other primary objectives such fisheries management or recreation have not been examined.

4.1 Summary of findings

There is a considerable and growing body of scientific literature describing the effects of MPAs on marine biodiversity. This report summarises what is now a large body of evidence of positive effects of MPAs on marine biodiversity, using examples mostly from temperate regions of the world. There are also circumstances where no discernable effects have been observed, where there are apparently negative effects or where there are insufficient data to take a view. Examples of these circumstances are also included in the report. A variety of effects may also be seen within a single MPA.

The nature and significance of reserve effects can be difficult to interpret and compare. Complicating factors include the absence of baseline data, different management regimes and levels of protection (which can range from HPMRs to multiple-use), the size of the MPA, the effectiveness of enforcement and the baseline conditions. There are also complications in monitoring complex and dynamic ecosystems. The timescale over which effects become apparent can be difficult to predict. In some cases changes have been observed almost immediately and in others not at all or over very long time scales. Any effects also need to be set into the context of natural variability and global trends, such as those associated with climate change. Taking these issues into account, more than two hundred studies on the effects of MPAs, were published in the peer reviewed primary literature between 1990 and 2001.

This report presents evidence for the beneficial effects of MPAs (both HPMRs and multiple-use areas) in relation to:

- conservation of biodiversity;
- habitat protection;
- commercial species (as a result of biodiversity conservation measures rather than fish stock management);
- protection or enhancement of ecosystem services; and
- insurance against environmental or management uncertainty.

The benefits of networks of MPAs are also discussed but data available to assess their effects are limited as few MPA networks exist.

4.1.1 Biodiversity conservation

The most systematic analysis of MPA effects to date, where there is good comparable data for HPMRs suggests overwhelming positive effects on biodiversity. These were apparent as higher densities, biomass, size and diversity of certain species or groups of species within HPMRs compared to outside them, or after reserve establishment compared to before. These benefits have also been reported from multiple-use MPAs which include HPMRs. There is also some evidence of positive species community effects such as greater complexity of food webs and increased primary and secondary productivity in MPAs as a consequence of protection.

4.1.2 Habitat protection

Reported habitat protection benefits of MPAs fall into two categories; preventing or reducing the impact of human activities, and providing conditions free from recurring impact thus allowing time and space for recovery and restoration. There is an abundance of evidence from studies carried out in the UK as well as other parts of the world that particular activities have damaging effects on marine habitats and that, in some cases at least, ‘recovery’ to pre-impact conditions is possible when those activities are discontinued. This can be in HPMRs or multiple-use MPAs. Quantitative evidence to support these views, from studies on demersal fishing gears, aggregate extraction and the disposal of dredge spoil, are presented in the report.

4.1.3 Benefits for commercially exploited species

The role of HPMRs and multiple-use MPAs for fisheries management was not discussed in this report however commercially exploited species have been shown to benefit from such MPAs set up for biodiversity conservation. Evidence for increases in densities, size and abundance of commercial species of fish and shellfish and also spill over from HPMRs to surrounding areas within temperate environments is presented in the report.

4.1.4 Ecosystem Services

The most direct evidence that MPAs can protect and enhance ecosystem services comes from situations where habitats and species protected by MPAs are known to provide specific ecosystem services whether in HPMRs or multiple-use MPAs. By way of illustration, the report presents evidence on the role of seagrass beds, kelp forests, mussel beds, maerl beds and sediment communities in supporting ecosystem services such as productivity, sedimentation, stablisation, oxygenation, shoreline protection, sediment production and nutrient recycling. Continuation of such services will be part of healthy functioning ecosystems.

4.1.5 Insurance

The potential for MPAs to act as insurance against environmental or management uncertainty is promoted as a biodiversity conservation benefit. This role has also been agreed as an objective of individual MPAs but has still to be tested.

4.1.6 Scientific investigation and education

There are many examples of MPAs being used for scientific investigation and education. HPMRs have been used as reference sites for monitoring the impacts of human activities, for example, while the UK Marine SACs Project has shown the educational potential and use of multiple-use MPAs.

Not all studies into the effects of individual MPAs reveal positive effects on marine biodiversity. Negative effects may result from attracting activities into an MPA or increasing pressure outside the MPA by displacing activities. Within MPAs negative effects are therefore most likely to be due to poor management or limited understanding of the carrying capacity of the site.

Impacts outside MPAs demonstrate problems with the wider management regime rather than failure of the MPA and highlight the importance of MPAs being set into a wider marine management context rather than isolated islands of biodiversity conservation.

4.2 Conclusions

The following conclusions are based on a review of the scientific literature describing the findings of field studies in and around MPAs.

- There are many examples of reserve effects associated with HPMRs and multiple-use MPAs.

- A variety of effects may be apparent within a single MPA and the significance of observed effects may be difficult to determine especially if there are no data on the pre-reserve conditions.
- There is a wealth of evidence that MPAs benefit marine biodiversity and that they have done so in temperate ecosystems, especially in HPMRs.
- Most of the documented evidence for benefits is in relation to species, habitats and ecosystem services.
- Some commercially exploited species and stocks can benefit from MPAs set up for biodiversity conservation.
- There is evidence of benefits from both HPMRs and multiple-use MPAs but most of the quantified evidence has come from HPMRs.
- The time scale over which effects become apparent can vary considerably. In some cases changes have been observed almost immediately and in others not at all or over very long time scales.
- There is very little evidence of negative effects on marine biodiversity within MPAs.
- The benefits of MPAs as insurance have still to be tested.
- MPA networks are mostly at the early stages of development and therefore there is limited data to quantify any network effects.
- There is evidence of effects on marine biodiversity outside the boundaries of MPAs. These can be negative when displaced activities increase pressure on surrounding resources or positive when activities outside the MPA have been enhanced. This issue demonstrates the critical importance of MPAs being set into a wider marine management context rather than isolated islands of biodiversity conservation
- Data, monitoring programmes and improved methodologies will provide more evidence and understanding of the effects of MPAs.

MPAs have many roles and are one of a number of management tools which can be used for the conservation of marine biodiversity. This report provides evidence of many positive effects of Marine Protected Areas on marine biodiversity.

In conclusion, there is overwhelming evidence of the benefits of MPAs for marine biodiversity and these are clearest and most significant in the case of Highly Protected Marine Reserves.

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Marine Protected Areas
A review of their use for delivering marine biodiversity benefits

Report Author: Susan Gubbay Date: August 2006
Keywords: Marine Protected Areas, Highly Protected Marine Reserves, marine sites, review

Introduction

The UK is committed to identifying and designating relevant areas of the UK's seas as areas of protection belonging to "a network of well-managed sites by 2010". As part of this, the Government is also considering the role Marine Protected Areas (MPAs) can play in ensuring functioning and resilient ecosystems and the protection of biodiversity.

What was done

This report examines the evidence for benefits from MPAs set up for the conservation of marine biodiversity and across the full spectrum of management regimes from Highly Protected Marine Reserves (HPMRs), where all extraction is prohibited, to multiple-use management areas

Evidence for the beneficial effects of MPAs is described in relation to:

- conservation of biodiversity;
- habitat protection;
- commercial species (as a result of biodiversity conservation measures rather than fish stock management);
- protection or enhancement of ecosystem services; and
- insurance against environmental or management uncertainty.

The value of MPAs for scientific research, education and raising awareness about the marine environment are also touched on briefly.

Results and conclusions

The most systematic analysis of MPA effects to date, where there is good comparable data for HPMRs suggests overwhelming positive effects on biodiversity. These were apparent as higher densities, biomass, size and diversity of certain species or groups of species within reserves compared to outside reserves, or after reserve establishment compared to before. There is also some evidence of positive species and community effects such as greater complexity of food webs and increased primary and secondary productivity in MPAs as a consequence of protection. Some commercially exploited species have been shown to benefit from MPAs set up for biodiversity conservation.

Reported habitat protection benefits of MPAs fall into two categories: preventing or reducing the impact of human activities; and providing conditions free from recurring impact thus allowing time and space for recovery and restoration.

The most direct evidence that MPAs can protect and enhance ecosystem services comes from situations where habitats and species protected by MPAs are known to provide such services. By way of illustration, the report presents evidence on the role of seagrass beds, kelp forests, mussel beds, maerl beds and sediment communities in supporting ecosystem services such as productivity, sedimentation, stablisation, oxygenation, shoreline protection, sediment production and nutrient recycling.

Continued……

The potential for MPAs to act as insurance against environmental or management uncertainty is promoted as a biodiversity conservation benefit. This role has also been agreed as an objective of individual MPAs but has still to be tested.

There are many examples of MPAs being used for scientific investigation and education. HPMRs have been used as reference sites for monitoring the impacts of human activities, for example, while the UK Marine SACs LIFE Project has shown the educational potential and use of MPAs.

Not all studies into the effects of individual MPAs reveal positive effects on marine biodiversity. Negative effects may result from attracting activities into an MPA or increasing pressure outside the MPA by displacing activities. Within MPAs negative effects are most likely to be due to poor management or limited understanding of the carrying capacity of the site. Impacts outside MPAs demonstrate problems with the wider management regime rather than failure of the MPA. They highlight the importance of MPAs being set into a wider integrated marine management context rather than isolated islands of biodiversity conservation.

MPAs have many roles and are one of a number of management tools which can be used for the conservation of marine biodiversity. This report provides evidence of many positive effects of MPAs on marine biodiversity. The conclusion is that there is overwhelming evidence of the benefits of MPAs for marine biodiversity and that these benefits are clearest and most significant in the case of Highly Protected Marine Reserves.

English Nature's viewpoint

This report provides an excellent summary of the advantages and disadvantages of Marine Protected Areas drawn from real examples. English Nature notes that the evidence supports the case that MPAs provide overall benefits to marine biodiversity. English Nature will use the evidence compiled in this report to support the case for the development of a UK-wide system of Marine Protected Areas, including Highly Protected Marine Reserves, for marine biodiversity, particularly in the context of the Government's Marine Bill.

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