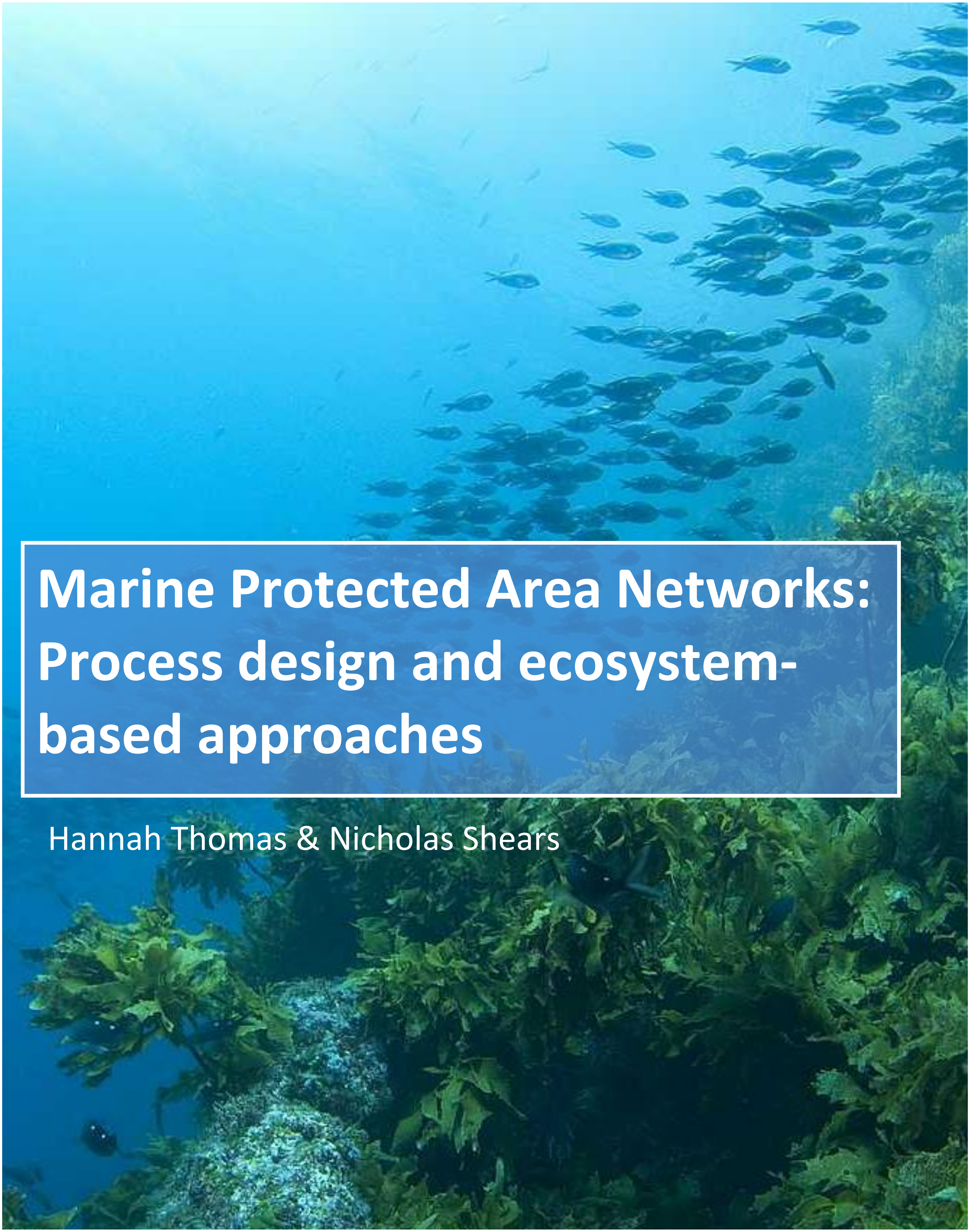

Marine Protected Area Networks: Process design and ecosystem-based approaches

Hannah Thomas & Nicholas Shears

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Executive Summary and Recommendations

New Zealand's long history of marine life protection is impressive compared to other efforts elsewhere in the world, being one of the first countries to establish a number of highly protected Marine Protected Areas (MPAs), or 'Marine Reserves'. However, New Zealand's marine reserves were established individually and independently to protect local-scale marine wildlife, rather than systematically as a coherent network designed to protect national-scale biodiversity and ecosystem services. In total, only 7% of New Zealand territorial waters are protected in marine reserves, but most of this lies offshore, leaving just 0.3% of mainland waters protected within reserves.

As part of its programme to develop positive and visionary campaigns for New Zealand's sustainable future, the Royal Forest and Bird Protection Society of New Zealand commissioned this report to inform their oceans management policy and to support their comments on emerging proposals for new MPAs in New Zealand. The objectives of the report were to: 1) review a selection of recent MPA network design processes from around the world, 2) summarise the key issues emerging from the scientific literature used to design MPA networks, 3) develop recommendations for future MPA design processes, particularly in relation to no-take zones and the New Zealand MPA Policy, and 4) highlight examples of the benefits of MPAs to fisheries.

We selected three MPA network design processes as **relevant case studies**: 1) the California Marine Life Protection Act Initiative; 2) the UK Marine Conservation Zones Project; and 3) the Australian Great Barrier Reef Marine Park Representative Areas Program. These case studies were specifically chosen because they used the latest scientific literature to guide their MPA network design guidance, and because of their similarities to New Zealand's MPA process in terms of spatial scale, marine environment, stakeholder engagement and socio-economic landscape.

<u>Ecological Design Guidelines</u>

Using explicit and, where appropriate, numerical guidelines is extremely important for the design process, as this provides stakeholders with scientifically justifiable "rules of engagement" for MPA planning and also provide managers with a quantitative framework with which to evaluate MPA network proposals. All three case studies developed strong science guidelines for achieving long-term biodiversity persistence within MPA networks, consisting of a scientific literature review and expert advice to produce a series of general principles or 'rules of thumb', often accompanied by clear numerical targets. Although the case study guidelines were not identical, the key principles that formed the basis of their network design processes could be identified as: 1) habitat; 2) *adequacy* of habitat coverage; 3) *viability* of MPA size; 4) *replication* of habitats in MPAs; 5) *connectivity* between MPAs; 6) using *best available evidence*; and 7) *levels of protection* (variety of MPA types and amount of habitat in no-take zones). Although many of these aspects are included to some extent in the existing NZ MPA Policy guidelines, we provide some recommended revisions of these guidelines to bring New

Zealand's efforts more in line with international design processes. Our recommendations for ecological design guidelines are:

1) **All habitats are represented in the network.** The appropriate habitat classification should match the spatial scale of the conservation planning efforts and ecosystem processes should be represented.
2) **Enough of each specific habitat should be included in the network to be functionally protected**. If sufficient biodiversity data permit, habitat-specific targets would be recommended. In the absence of such data, we would recommend rigorous application of other scientifically robust design principles (e.g. viability, connectivity and representativity).
3) **MPAs should be large enough to cover the majority of species adult movement distances**. Based on these case studies and extensive studies from existing New Zealand reserves, we would recommend that MPAs have a minimum coastline length of 5-10 km, preferably 10-20 km, and should extend along the depth gradient from intertidal to deeper offshore waters, preferably to the 12 nautical mile limit.
4) **Several examples of each habitat should be included within separated MPAs**. A precautionary number of replicates would be 3, with two replicates being the minimum.
5) **The spacing between MPAs should allow larval dispersal to occur.** We recommend that MPAs, with similar habitats where possible, should be placed within 50-100 km of each other.

<u>Levels of Protection</u>

The level of protection afforded to a MPA defines the MPA's status or type (e.g. 'marine reserve') and the varying activities that are managed or restricted within its boundaries, potentially ranging from multiple uses to no-take and even no-entry zones. Processes that have successfully established ecologically robust MPA networks over large spatial scales typically have no-take zones at their core. The level of protection required for an MPA in a particular area is dependent on the goals of the MPA design process and also the level of activities that already occur in an area. If the goal of the MPA process is biodiversity protection and long-term persistence, then it is essential that any permitted activities do not compromise this goal. These goals and the required levels of protection must be made clear in order to ensure stakeholders involved in the design process are in no doubt of the expected outcomes, thereby increasing the likelihood of a successful MPA planning process.

Although partially protected multiple-use MPAs can play an important role in protecting sensitive habitats and benthic ecosystems against particularly destructive fishing practices, such as trawling, it is clear from the literature that these MPAs have limited conservation benefits compared to no-take zones. Even relatively low levels of fishing pressure can suppress many populations and prevent recovery, and fishing methods that are allowed to continue in an MPA tend to "take up the slack" in terms of catching the fish that may otherwise have been caught by the prohibited methods.

The appropriate proportion of no-take zones for adequate ecosystem protection is likely to be driven by specific network goals, spatial extent, sensitive habitats and levels of human activity in the area of intervention. A wide range of no-take zone targets exists for both global ocean management and within specific MPA network designs, ranging from 10-75% coverage of a given area. However, some network design processes have replaced a pre-determined target with very clear ecological design guidelines for replication, viability, connectivity and levels of protection in order to establish, by default, a proportion of no-take zones that is appropriate to the conservation needs of a given region. Although the current New Zealand MPA Policy was written to achieve the objectives of the New Zealand Biodiversity Strategy, which aims to protect 10% in marine reserves, it lacks clear design guidance on the required level of protection. Our recommendations for levels of protection are:

1) **No-take zones are considered a critical part of any MPA network design** for:
    a. ***Maximum conservation benefits*** – No-take zones ensure a high level of protection for biodiversity structure and function, they remove uncertainty regarding the impacts of activities and they have been shown to deliver significant ecological direct and indirect benefits for fisheries and biodiversity, in tropical and temperate areas.
    b. ***Simplicity and cost-effectiveness from a management perspective*** – There is no doubt for users over what activities are allowed within an MPA, making enforcement easier and compliance higher.
    c. ***No preference for certain stakeholder groups*** – Establishing no-take zones for everyone can be less controversial than identifying selective use zones.
    d. ***Provide insurance against changes in future use*** – No-take zones remove the risk of permitted activities increasing in intensity in the future following an MPA establishment, either due to subsequent changes in user behaviour or general population increases.
2) **New Zealand MPA policy guidelines and process are strengthened so that the levels of protection are sufficient to protect biodiversity.** The amount of no-take zones incorporated into the network can be determined in several ways but the associated guidelines should be explicit and criteria-driven so that stakeholder progress can be evaluated and any proposals can be justifiably assessed according to the necessary goals.
3) **Ensure that establishing the level of protection afforded to MPAs (i.e. no-take vs. restricted fishing) is an integral, justifiable and transparent part of the stakeholder design process.** This aspect is so important to the success of the process that it must be very closely associated with any consideration of spatial areas.

<u>Fisheries benefits from MPAs</u>

MPAs, being permanent, have historically been used as a conservation tool to protect threatened habitats, whereas fisheries management areas tend to be temporary closures. It is now being increasingly encouraged that MPAs be utilized as an ecosystem-based approach to managing our natural resources, particularly fisheries. Global analyses of numerous marine reserves throughout the world are consistent in showing that on average, the majority have had a positive effect on previously harvested species, with some impressive increases in biomass, density, size and species richness within their boundaries, often within short timescales and for both temperate and tropical ecosystems alike. Some larger reserve networks like the Great Barrier Reef Marine Park are also seeing benefits to larger, more mobile species, such as dugongs, turtles and sharks.

In the past, several studies have concluded that MPAs can provide some benefits to fisheries through the 'spill-over' of adult target species. With recent technological developments, researchers are now demonstrating a much greater and more important contribution of MPAs to wider fished populations through the export of larvae. Continual improvements in our knowledge and useful lessons learned means that designing reserves specifically for both fisheries and conservation benefits is technically possible and highly desirable, but most current MPAs are too small to deliver the biological conditions necessary to promote fishery recoveries. The vast majority are still single, isolated reserves without the multiplicative benefits provided by large networks of no-take and multiple use MPAs. Analysis of existing reserve performance has led to clearer science guidelines in future network design to achieve improved fisheries benefits without the implicit trade-off against conservation goals, but progress in this direction will require greater collaboration between fisheries and conservation to achieve successful ecosystem management.

Abbreviations

BOP	Biophysical Operating Principles (Australia)
BZ	Buffer Zones (Australia)
CBD	Convention on Biological Diversity
CIZ	Commonwealth Island Zones (Australia)
CPZ	Conservation Park Zones (Australia)
DEFRA	UK Department of Environment, Food and Rural Affairs
EEZ	Economic Exclusion Zone
EUNIS	European Nature Information System
GBRMP	Great Barrier Reef Marine Park (Australia)
GBRMPA	Great Barrier Reef Marine Park Authority (Australia)
GBRMP RAP	Great Barrier Reef Marine Park Representative Areas Program (Australia)
GUZ	General Use Zones (Australia)
IUCN	International Union for the Conservation of Nature
IUCN-WCPA	IUCN – World Commission on Protected Areas
HPZ	Habitat Protection Zones (Australia)
JNCC	Joint Nature Conservation Committee (UK Statutory Nature Conservation Body)
MCZ	Marine Conservation Zones (UK)
MLPA	Marine Life Protection Act (California)
MNPZ	Marine National Park Zones (Australia)
MPA	Marine Protected Area
NE	Natural England (UK Statutory Nature Conservation Body)
NTA	No take area (Australia)
NTZ	No take zone
OSPAR	Oslo Paris Convention (North East Atlantic Regional Seas Convention)
PZ	Preservation zones (Australia)
SAC	Special Area of Conservation (UK)
SMCA	State Marine Conservation Area (California)
SMP	State Marine Park (California)
SMR	State Marine Reserve (California)
SPA	Special Protection Area (UK)
SRZ	Scientific Research Zones (Australia)
SSSI	Site of Special Scientific Interest (UK)

Table of Contents

Introduction

Context

New Zealand demonstrated its early commitment to marine conservation through the establishment of a Marine Reserves Act in 1971, followed shortly afterwards by one of the world's first marine no-take reserves at Cape Rodney-Okakari Point, also known as Goat Island, in 1975. The creation of the Poor Knights Marine Reserve in 1981 and the Kermadec Islands Marine Reserve in 1990 continued this exemplary trend in strong, forward-thinking marine conservation action and a total of 34 highly protected marine reserves are currently in place.

Although New Zealand's long history of marine life protection is impressive compared to other efforts elsewhere in the world, these New Zealand reserves were established individually and independently, rather than systematically as a coherent network designed to protect biodiversity and ecosystem services at a national scale for the long-term. In total, only 7% of New Zealand territorial waters are protected in marine reserves and the two reserves making up the greatest proportion of this coverage - the Kermadec Islands and the Auckland Island (Motu Maha) reserves – are situated considerably offshore, leaving just 0.3% of mainland waters protected within reserves.

In 2000, the New Zealand Department of Conservation reviewed the Marine Reserves Act (1971) and subsequently drafted a new Marine Reserves Bill, which is currently reaching its concluding stages. A recent review of New Zealand's current MPA planning framework and a comparison with international developments by Mulcahy, Peart and Bull[1] has identified an urgent need to develop new MPA legislation in New Zealand. Mulcahy *et al.* (2012) provide a series of recommendations on how legislative reform should proceed. This reflects similar changes occurring internationally, as Australia[2], California[3], Canada[4] and the UK[5] reviewed and strengthened their marine laws to pave the way for systematic planning of marine protected area (MPA) networks for greater biodiversity protection. Accompanying the new marine policies, there has also been an associated shift towards encouraging far greater participation from local people and marine users in the design of MPAs, in part to increase support and compliance for the overall outcomes, but more importantly to accompany the positive momentum around the 'ecosystem approach' to marine protection and the need to develop integrated management to accommodate both ecosystem dynamics and human resource requirements.

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[1] Mulcahy, K, Peart, R, Bull, A. 2012. Safeguarding our Oceans: Strengthening marine protection in New Zealand. Environmental Defence Society

[2] Environment Protection and Biodiversity Conservation Act 1999

[3] Marine Life Protection Act 1999

[4] National Marine Conservation Areas Act 2002

[5] Marine and Coastal Access Act 2009

Objectives

As part of its programme to develop positive and visionary campaigns for a sustainable future, Forest and Bird (F&B) commissioned this report to inform their oceans management policy and to support their comments on emerging proposals for new MPAs in New Zealand.

The objectives of the report were to:

1. Review a selection of recent MPA network design processes from around the world
2. Synthesize the key issues emerging from the scientific literature used to design MPA networks in other countries
3. Develop high-level recommendations for future MPA design processes, particularly in relation to no-take zones and the New Zealand MPA Policy
4. Highlight examples of the benefits of MPAs to both biodiversity and fisheries

In contrast to the review of Mulcahy *et al.*, which focuses on reviewing the legislative side of MPA planning in New Zealand and overseas, our report concentrates on the ecological aspects of designing MPA networks. It is envisaged that the results of this report will complement those of Mulcahy et al. and provide the scientific guidance necessary for designing comprehensive MPA networks in New Zealand.

Selecting case studies

To meet the first three objectives of this report, we selected a small number of MPA network design processes as appropriate and relevant case studies: 1) the California Marine Life Protection Act Initiative ("MLPA Initiative"); 2) the UK Marine Conservation Zones Project ("UK MCZ Project"); and 3) the Australian Great Barrier Reef Marine Park following its Representative Areas Program ("GBRMP RAP").

These case studies were specifically chosen for their similarity in MPA network design approach, as well as their relevance to the New Zealand process in terms of spatial scale, marine environment and socio-economic landscape. All three case studies are large-scale MPA network implementation processes systematically designed to establish an ecosystem approach to protection of the marine environment. All three were required to use the best available scientific understanding and evidence to guide their outcomes, and therefore raise the key marine issues that emerge from this scale of process. Since the temperate UK and California marine environments may be considered to contain functionally similar ecosystems to those in New Zealand, they should provide applicable ecological guidance. Situated within similar socio-economic and socio-political contexts, all three case studies had legislation in place with a mandate to use a participatory approach that involved stakeholders at all stages of the process, and took some account of the socio-economic implications of MPA designation on stakeholders.

Exploring the similarities of these case study processes can provide strong recommendations for other such processes. In addition, the finer scale differences between them in terms of local ecosystems, human activities and policy frameworks, have resulted in methodological variations in implementation, and identifying these can provide extremely interesting points of comparisons and lessons to be learned. Therefore the main focus of this report is to compare and contrast these approaches, highlight the process outcomes and suggest what considerations would be advisable for a similar process in New Zealand.

Report structure

The report is divided into three major chapters:

Chapter 1) Overview of the case study and New Zealand MPA network design processes

Chapter 2) Scientific guidelines for designing MPA networks

Chapter 3) Benefits of MPAs to conservation and fisheries

Chapter 1 describes the case studies in turn, giving an overview of their legal mandates, geographical location and coverage, start and finish dates, general process structure and current status, with outcomes where appropriate. A summary of the current New Zealand MPA process is also given.

Chapter 2 looks at the scientific guidelines that were followed by each case study, and describes the different approaches. These design guidelines are divided into two parts; ***Part 1*** looks at the ***ecological design guidelines*** that are common to all three processes, and ***Part 2*** describes the ***levels of protection*** in an MPA network, outlines the importance of highly protected areas (i.e. marine reserves), reviews the literature on how much habitat should be captured within highly protected areas, and how the case study outcomes were affected by the different ways in which the international case studies incorporated levels of protection into the planning process.

Both Parts 1 and 2 have a recommendations section at the end that compares the case study design guidelines with those in the New Zealand MPA Process.

Finally, **Chapter 3** looks at the benefits of MPAs and MPA networks to both fisheries and conservation by reviewing the large body of published literature dealing with theoretical and empirical research on individual MPAs as well as MPA networks. For the purposes of this report, we gathered published and unpublished literature and information on the three case studies.

Chapter 1: Overview of the case studies and New Zealand MPA network design processes

Case Study no 1: Australia's Great Barrier Reef Marine Park Representative Areas Program (GBRMP RAP process)

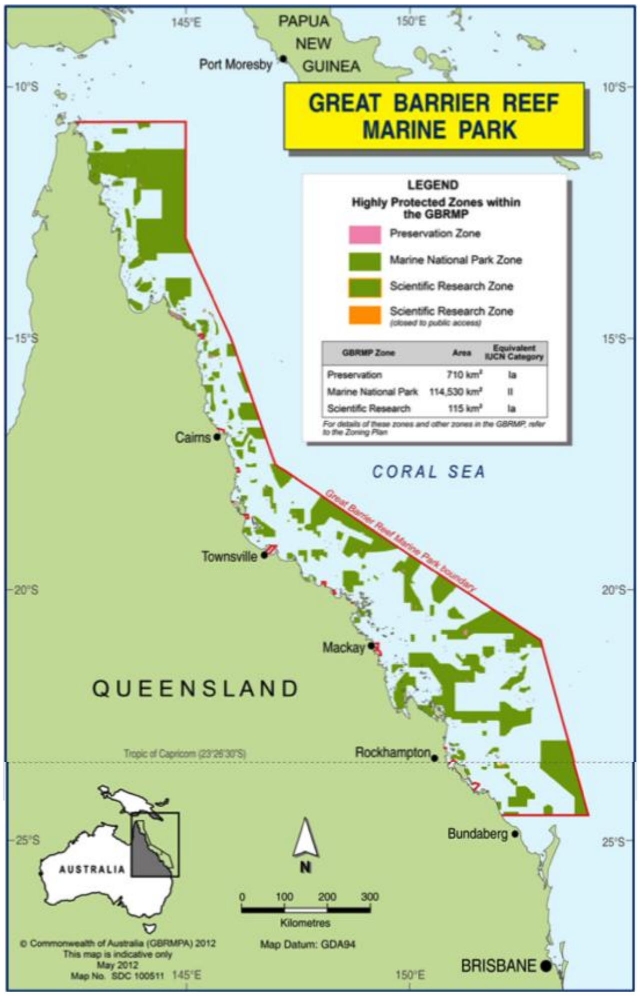

Figure 1. The Great Barrier Reef Marine Park

The Marine Park was created in 1975 by the Great Barrier Reef Marine Park Act (1975). The initial zoning of the GBR Marine Park was done in Sections, beginning in 1982, with the entire Marine Park being zoned at least once by 1988 and various sections being subject to review in the period 1988–99 [1].

The GBRMP is designed as a multiple use park regulated through a system of 8 zones specifying allowed activities. Following a review of the zoning plan, the GBRMP Authority and a Scientific Steering Committee agreed that protection was insufficient for many habitats and was not comprehensive across the different bioregions. In 2002 public participation was invited on a new rezoning plan, called the Representative Areas Program, designed to increase the amount of each habitat protected within no-take zones in order to ensure adequate protection across the Great Barrier Reef. This process focused on establishing new no-take zones but also addressed other issues to improve the entire GBRMP zoning plan (e.g. zone boundaries were amended, additional mitigation measures were established for selected activities, the zoning plan was standardized, protection measures for some fish species were increased). The new Zoning Plan was completed in 2004 and included 33.5% highly protected areas and 31% habitat protection zones.

Table 1. Great Barrier Reef Marine Park Representative Areas Program (GBRMP RAP)

Dates	Original GBRMP zoning established in 1975; RAP dates 2002 - 2004
Status	Complete: zones designated in 2004.
Outcome	An improved Zoning Plan with no-take zones increased from 3% to 33.5%
Legislation	GBRMP Act (1975)
Policy	Australia's Ocean Policy [2]
Extent	Between 60 and 250 km wide, the Park covers a total area of 344,400km^2 from the northern tip of Queensland, NE Australia, to just north of Bundaberg, close to the easternmost point of Australia. It has an average depth of 35 m in its inshore waters, while on outer reefs, continental slopes extend down to >2km.
Ecosystems	The world's largest coral reef ecosystem, protecting some 3000 coral reefs, 600 continental islands, 300 coral cays and about 150 inshore mangrove islands.
Governing agency	Great Barrier Reef Marine Park Authority
Fisheries objectives	Not the priority of the rezoning process, but the GBRMP had strong provision for fisheries within its existing zoning plan and this was maintained.
Goals	• Maintain biological diversity at ecosystem, habitat, species, population and gene level • Allow species to evolve and function undisturbed; • Provide an ecological safety margin against human-induced impacts; • Provide a solid ecological base from which threatened species or habitats can recover or repair themselves; • Maintain ecological processes and systems
Guidelines	11 Biophysical Operating Principles and 4 Socio-economic Principles were recommended by the Scientific Steering Committee and other experts (see Appendix 1)
Governance structure	• GBRMP Authority • Scientific Steering Committee • Social, Economic and Cultural Steering Committee • Public consultation via submissions
Process stages	1) Describe the biological diversity 2) Review of existing protection 3) Develop Biophysical Operating Principles 4) Formal community participation process 5) MPA submissions received a. Draft zoning plan produced and opened to public consultation b. Preparation of revised zoning plan c. Ministerial review and approval 6) Zoning plan adopted
Types of MPAs	• Preservation zones (No entry) • Marine National Park Zones (No take, some traditional use) • Scientific Research Zones (No take, some traditional use) • Buffer Zones (Trolling only, usually surround no-take zones) • Conservation Park Zones (restricted fishing) • Habitat Protection Zones (no trawling) • General Use Zones • Commonwealth Island Zones (no take, some low impact activities)

Case Study no 2: California Marine Life Protection Act Initiative (MLPA Initiative)

The Marine Life Protection Act was established in 1999 to increase protection for the coastal marine environment following the claim that existing MPAs in state waters were deemed be too small to be effective and had been set up individually without a coherent plan or clear scientific guidelines. In 1998, following requests from the local fishermen, the California Fish and Game Commission established a multi-agency and multi-stakeholder process to create 12 fully protected marine reserves in the state waters around the California Channel Islands, which were designated in 2003 [1,3]. Following that process, three attempts were made to implement the MLPA across the entire state waters of California.

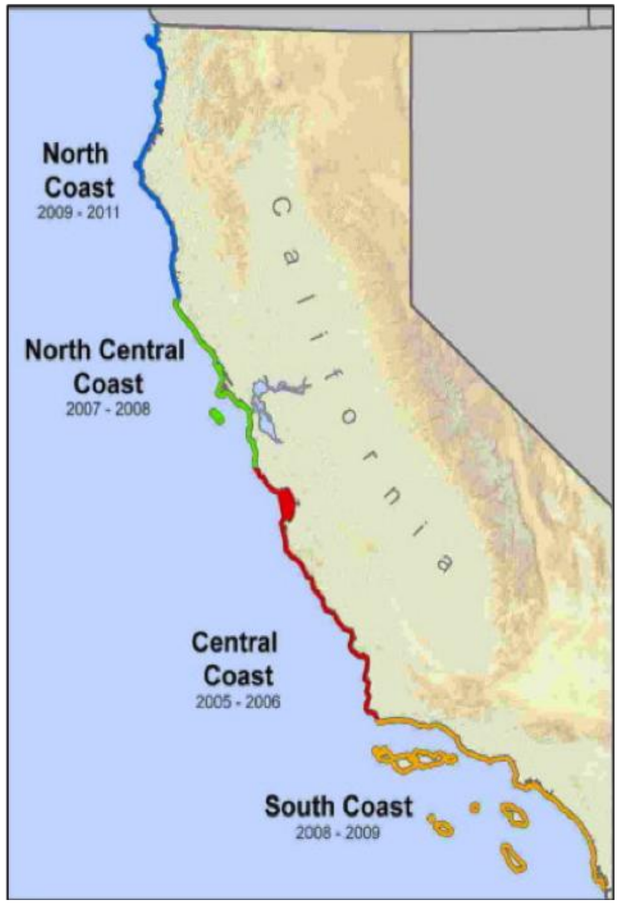

Figure 2. The four regional study zones within the MLPA Initiative

The previous two attempts (2000, 2002) failed due to insufficient resources and resistance from stakeholders to accept initial MPA proposals developed largely by scientists [4]. The third attempt was established in 2004 as a public-private initiative and was implemented sequentially across four study regions (see Figure 2). This final MLPA Initiative was successfully completed in 2011 and MPAs were designated in 2012. Approximately 9% of state waters are now protected in highly protected areas and about 6% as partially protected MPAs.

Table 2. California Marine Life Protection Act Initiative (MLPA Initiative)

Dates	2000 and 2002 (unsuccessful); 2004 – 2012 (process and final designation of all four regions)
Status	Complete; zones designated
Outcome	A total of 124 MPAs designated (including 12 California Channel Islands MPAs), covering 16.0% of total state waters (2197 km^2), 61 of which were no-take zones covering 9.4% of state waters (1281 km^2)
Legislation	Marine Life Protection Act 1999
Policy	MLPA Master Plan [5]
Extent	Mean High Water to 3nm offshore along total length of the California coastline
Ecosystems	Temperate rocky reefs, intertidal zones, sandy or soft ocean bottoms, underwater pinnacles, kelp forests, submarine canyons, and seagrass beds.
Governing agencies	California Fish and Game Commission; California Department of Fish and Game; California Resources Agency
Fisheries objectives	Selected commercial fish species and populations were included for protection
Goals	• Protect marine biodiversity • Protect and restore marine life populations • Improve recreational, educational and study opportunities in MPAs while maintaining their objectives of protecting biodiversity • Protect marine life heritage for the inherent value of habitats • Ensure MPAs have clear objectives, effective management measures, adequate enforcement and are based on sound scientific guidelines • MPAs are designed and managed as a network
Guidelines	9 scientific 'guidelines' covering ecological and human aspects of design. 2 socio-economic guidelines to take account of local resource use/stakeholder activity and adjacent human environment
Governance structure	• Blue Ribbon Task Force – managed and guided the planning process • Science Advisory Team – developed science guidelines • Project Teams – managed the regional planning process with stakeholders • Regional Stakeholder Group – developed recommendations • Statewide Interests Group – improved public involvement in the process
Process stages	1) Project preparation a) Develop guidelines b) Identify stakeholders 2) Develop ecological/social profile of the region 3) Convene regional stakeholder group planning process (in three iterations) a) Establish MPA sites to meet guidance b) Assemble draft regional MPA networks c) Evaluate draft regional MPA networks 4) Review of proposals 5) Public consultation 6) Designation
Types of MPAs	• SMCA – State Marine Conservation Area • SMP – State Marine Park • SMR – State Marine Reserve

Case Study no 3: United Kingdom Marine Conservation Zones Project (UK MCZ Project)

The Marine and Coastal Access Act was signed in 2009, requiring a network of MPAs in UK waters. Although a number of European MPAs already existed in British waters (the "Natura 2000" sites protecting habitats of European importance), the MCZ designation type aimed to protect representative examples of nationally important habitats (as well as nationally rare and threatened species and habitats), and was also an attempt to integrate all the various MPA designations into a single ecologically coherent network.

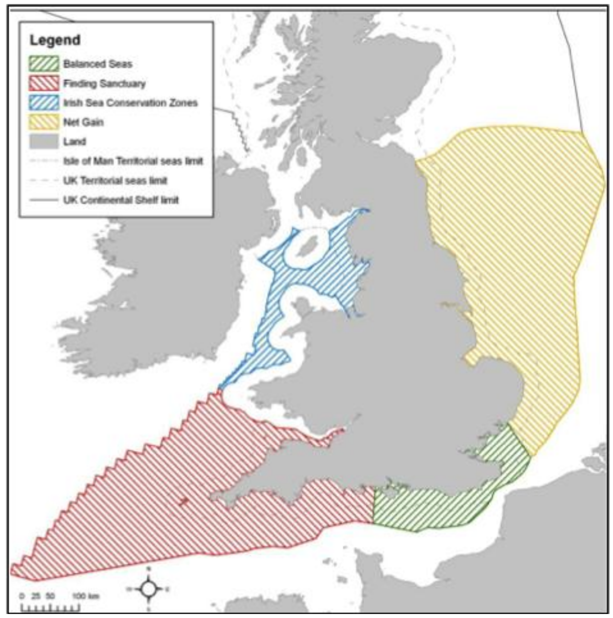

Figure 3. The four MCZ Regional Projects

England began its stakeholder participation phase in 2009, but Scotland, Wales and Northern Ireland chose to adopt differing approaches that resulted in them commencing their MCZ projects at a later date. The UK MCZ Project in English waters was undertaken in four regions simultaneously (see Figure 3). Recommendations for a network of 127 sites were submitted to the Government in 2011 and in December 2012, 31 of those were selected for potential designation in 2014, subject to public consultation. As the process has not yet reached designation stage, the likely outcome is uncertain. Stakeholders recommended approximately 15% of England's EEZ to be protected within 127 MPAs and approximately 1.9% in 65 highly protected areas. At the present time, however, none of the 31 MPAs selected for potential designation in 2014 were to be highly protected.

Table 3. United Kingdom Marine Conservation Zones Project (UK MCZ Project)

Dates	2009 – present
Status	Recommendations (Sept 2011) followed by public consultation (Jan-Mar 2013). First set of 31 MPAs (none are highly protected) have been put forward for potential designation in 2014.
Outcome	As yet unknown. 127 MCZs (and 65 highly protected areas) were recommended by stakeholder groups (in 2011), but at the time of writing, the Government has selected only a first tranche of 31 MCZs for potential designation, with no highly protected areas.
Legislation	Marine and Coastal Access Act 2009
Policy	Guidance Note 1 [6] Ecological Network Guidance [7]

Extent	English waters from Mean High Water to 200nm (or neighbouring EEZ)
Ecosystems	23 Broad scale habitats were identified from the European classification system (EUNIS), describing biogenic reefs and intertidal, infralittoral, circalittoral and subtidal rock and mixed sediment habitats characterized by high, medium and low energy levels.
Governing agencies	Natural England (NE) and Joint Nature Conservation Committee (JNCC)
Fisheries objectives	None (the UK has a fisheries quota system established under the European Common Fisheries Policy)
Goals	MCZs may be designated to conserve and/or aid the recovery of: • The range of marine biodiversity in our waters; • Rare or threatened habitats and species; • Globally/regionally significant areas for geographically restricted habitats or species; • Important aggregations or communities of marine species; • Areas important for key life cycle stages of mobile species, including habitats known to be important for their reproduction and nursery stages; • Areas contributing to maintenance of marine biodiversity and ecosystem function; • Features of particular geological or geomorphological interest
Guidelines	7 Design Principles describe 19 ecological guidelines, with 11 additional 'further consideration' guidelines [7]. One overarching objective was to minimise the socio-economic impacts on stakeholder activity
Governance structure	• MCZ Project Team – managed and guided the process • Statutory Nature Conservation Agencies (JNCC/NE) – delivered the science guidelines and project delivery guidance • Science Advisory Panel – assessed the recommendations • Regional Stakeholder Groups – developed recommendations • Regional MCZ Project Teams – managed the planning process
Process stages	1) Project preparation a. Identify stakeholders b. Develop guidelines 2) Stakeholder group formation and data collation 3) Develop ecological/social profile of the region 4) Convene regional stakeholder group planning process (in three iterative stages) a. Establish MCZ sites b. Evaluation of progress c. Finalise recommendations 5) Develop Impact Assessment 6) Review of recommendations and formal submission to Government 7) Public consultation 8) Designation
Types of MPAs	MCZs are one type of MPA but can have any combination of restrictions depending upon the features for conservation and the impacts upon them. 'Reference Area MCZs' are highly protected areas with no extraction, deposition or disturbance

MPA network developments in New Zealand

In 2005, New Zealand released its Marine Protected Areas Policy and Implementation Plan (MPA Policy), the objective of which is to: "Protect marine biodiversity by establishing a network of marine protected areas that is comprehensive and representative of New Zealand's marine habitats and ecosystems" [8]. This policy was developed to achieve the objectives and actions of the New Zealand Biodiversity Strategy [9] and meet New Zealand's commitments to the International Convention on Biological Diversity. MPA planning for the coastal marine environment was to be implemented independently in the 14 biogeographic regions (Figure 4) through community-based Marine Protection Planning Forums (MPPFs).

Figure 4. Coastal marine biogeographic regions (bioregions) in the New Zealand Territorial Sea (within 12 nautical miles of coast and islands).

To date, MPFFs have been held for the Sub-Antarctic Islands, which are a UNESCO World Heritage Site, and the West Coast South Island. Recommendations for MPAs in both regions are both awaiting Government approval. For the remote Sub-Antarctic Islands, 39% of the Territorial Sea around Campbell Island, 58 % of the Territorial Sea around the Bounty Islands and all of the Territorial Sea around the Antipodes Islands are proposed within no-take zones. In contrast, 1.3% of the South Island West Coast will be protected in four no-take zones if the current proposal is approved. As part of the West Coast process two other MPAs were also proposed under the Fisheries Act 1996 that prohibited bottom trawling, dredging and Danish seining. If approved, the total level of marine protection achieved by the South Island West Coast MPPF will be 2%.

Currently the overall level of Type 1 marine reserve protection (i.e. no-take zones) for biogeographic regions around mainland New Zealand ranges from between 0 and 1% [10]. Similarly, the average coverage of Type 2 MPAs (i.e. prohibition of bottom trawling, Danish seining and dredging) across regions is about 1%.

Table 4. New Zealand MPA Policy

Dates	Started in 2005 and is currently underway
Status	Final decision pending for both regions following public consultation
Outcome	**South Island West Coast** - 4 NTZs (protecting 1.3% of the Territorial Sea) and 2 MPAs (0.7% of the Territorial Sea) recommended. **Sub-Antarctic Islands** - 3 NTZs were recommended protecting 39% of the Territorial Sea around Campbell Island, 58 % of the Territorial Sea around the Bounty Islands and all of the Territorial Sea around the Antipodes Islands.
Legislation	Marine Reserves Act 1971 (under review) Fisheries Act 1996
Policy	Marine Protected Areas Policy and Implementation Plan[8] 2005 (MPAPIP) Marine Protected Areas: Classification, Protection Standard and implementation Guidelines[11] 2008 (MPACPIG)
Extent	Entire marine environment including estuaries, the Territorial Sea (within 12 nautical miles of the coast and islands), and the Exclusive Economic Zone (12 to 200 nautical miles)
Ecosystems	Hierarchical coastal classification system: Biogeographic region (13) / Environment type (Estuarine/Marine) / Depth (Intertidal, 0-30 m, 30-200 m) / Exposure (low, med, high) / Physical habitat type (Mud, Sand, Rock etc)
Governing agencies	Department of Conservation; Department of Primary Industries (formerly Ministry of Fisheries)
Fisheries objectives	Not incorporated into MPA process
Goals	The MPA Policy objective is to: Protect marine biodiversity by establishing a network of MPAs that is comprehensive and representative of New Zealand's marine habitats and ecosystems [as required under the NZ Biodiversity Strategy (NZBS) 2000, ratification of the international Convention on Biodiversity]
Guidelines	Network Design Principles and Planning Principles (MPAPIP) Design guidelines used to identify and select potential protected areas (MPACPIG): - Site Identification and Protected Area Design Guidelines - Site selection guidelines - Tool selection guidelines
Governance structure	• Department of Conservation and Department of Primary Industries • Regional Marine Protection Planning Forums
Process stages	1-2. Develop classification approach and Refine the protection standard 3-6. Map existing management tools, develop MPA inventory, identify gaps prioritise new MPAs. 7-9. Nearshore implementation (regional approach), Offshore implementation and Designation of new MPAs 10. Monitor and evaluate MPA network
Types of MPAs	Two types of MPAs: Type 1 MPAs (marine reserves) and Type 2 MPAs (other management tools that meet the protection standard)

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Chapter 2: Scientific guidelines for designing MPA networks

Introduction and overview

Greater awareness of the need for increased marine protection and sustainable resource management has resulted in the development of MPA networks around the world. Achieving long-term biodiversity persistence within these MPA networks is more likely if their design is shaped by the best available scientific guidance on conservation planning for both population sustainability and ecosystem protection. Many such guidelines exist [1–8] and are being used as the foundation for MPA network design processes around the world.

Although the three case study processes are currently at different stages of implementation (see Chapter 1), all three developed strong science guidelines for MPA network development that essentially consisted of a scientific literature review and expert advice to produce a series of general principles or 'rules of thumb', often accompanied by clear numerical targets. This section of the report aims to compare and contrast the ecological principles that were used by these case studies, first describing the scientific research that underpins the guidelines and then providing comment on how effectively these guidelines were translated into actual reserve design, with recommendations for future processes.

Although the three case study guidelines are not identical, it is possible to distil out the key principles that form the basis of the network design process for all three, which are:

1. **Representativity** – including the full range of habitats to protect all biodiversity
2. **Adequacy** – ensuring sufficient habitat coverage for long term biodiversity persistence
3. **Viability** – ensuring MPAs are large enough to sustain and expand populations
4. **Replication** – including more than one example of each habitat to minimise risk
5. **Connectivity** – ensuring adult and/or larval organisms can move between sites
6. **Best available evidence** – using up-to-date information and local knowledge but ensuring the process is not delayed by the assimilation of better data
7. **Levels of protection** – including marine reserves in a network for the best ecological protection.

Part 1 outlines the first six guidelines, looking at the scientific literature underpinning them and how each of the case studies applied such science in practice. **Part 2** first explains the different levels of protection afforded to MPAs and examines the literature on what proportion of a marine environment should be included within marine reserves. It then describes how these levels of protection were incorporated into each of the three case study processes, what the respective outcomes were and how this might offer guidance to the New Zealand MPA process.

PART I – Ecological design guidelines

Representativity

Context and international case study application

Representativity[6], usually describes the goal of including samples of all organisational levels of biodiversity (i.e. habitats, communities, species and genes) within any established area boundaries [5,9]. This concept is sometimes referred to as 'comprehensiveness' [10], but should be distinguished from 'representativeness', which has been used (e.g. GBRMP) to refer to the selection of habitats or species that are typical of their kind [11].

Habitats can act as a surrogate for species in the planning process [12] but the full biogeographic range of habitats must be incorporated at the appropriate spatial scale in order to meet any objective to protect biodiversity [7,12]. When choosing the appropriate level of habitat classification for setting conservation objectives or targets, it is critical that the scale of habitat classification matches the scale of the spatial planning efforts in order to capture the variation in biological assemblages found at that local level [13,14]. Rice and Houston [15] suggest that the identification of larger scale, common habitats is appropriate, to avoid a situation where all fine-scale unique habitats need to be classified and therefore incorporated into the network. To capture locally important examples of biodiversity, representativity can often include rare species or habitats that are characteristic of the area. As well as habitats, incorporating ecological processes should also be considered (e.g. spawning grounds or productive upwellings) at sufficient sizes to ensure the persistence of species at all trophic levels [15]. Representativity can also be applied across disciplines, including valuable or important cultural or spiritual areas [1].

It was the recognition that habitats other than coral reefs were under-represented in the Great Barrier Reef Marine Park (GBRMP) that led to the Representative Areas Program (RAP) rezoning in 2004 [11,16]. Using biological and physical spatial datasets on the distribution of habitats, plants and animals, a team of over 60 GBRMP experts designed a classification scheme for the rezoning process, identifying 70 specific bioregions at a scale dictated by the amount of available data, the presence of habitat patterns, and the zoning extent [11]. In addition to special/unique places, the GBRMP RAP process also recommended 'cross-shelf and latitudinal gradients' be captured to ensure that the full diversity of habitats was represented.

To define the representative 'key habitats', the California MLPA Science Advisory Team used large-scale ecological, oceanographic and geological datasets to classify habitats according to two biological patterns, one described by community assemblage and the other by depth. This classification scheme was then revised to reflect the particular biogeography of each sub-regional planning area [17]. Additional habitat types defined by oceanographic process (e.g. upwellings, freshwater plumes, larval retention areas) were also included [18].

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[6] Also referred to in the literature as representivity or representation.

Classification of the UK marine environment falls within the revised Europe-wide comprehensive hierarchical system devised by the European Nature Information System (EUNIS) [19], encompassing terrestrial, marine and coastal environments from broad to fine scales and derived from analysis of physical and/or biological characteristics. The UK MCZ process used EUNIS broad-scale habitats as the basis for habitat representativity targets, supported by information on finer-scale habitats where available. Additional lists of habitats and species considered to be rare and threatened were also included, as specified in a range of national legislation [20]. Unfortunately, the EUNIS habitat definitions used to identify MCZs did not align well with the different habitat classification used to identify pre-existing UK MPAs, which created considerable challenges for the gap analysis undertaken to evaluate habitat protection within existing MPAs and additional effort required to achieve representativity in MCZs.

New Zealand context

The New Zealand Marine Protected Areas Policy's main objective is to 'protect marine biodiversity by establishing a network of MPAs that is [both] comprehensive and representative of New Zealand's marine habitats and ecosystems.' In order to achieve this, the policy aims to protect representative examples of the "full range of marine habitats and ecosystems", as well as outstanding, rare, distinctive or internationally or nationally important marine habitats and ecosystems. The policy also mandates a consistent approach to classifying habitats. In general this guideline is in accordance with the other international case studies.

Table 4. Representativity

MLPA Initiative	UK MCZ Project	GBRMP Representative Areas Program	NZ MPA Process
1) All key habitats should be protected (N.B. these were listed, with depth zones and important oceanographic habitats, but the list was often influenced by the regional composition of the SAT) 2) The network should include offshore open ocean to capture those areas that are critical for lifecycle stages 3) Habitats with unique features or those that are rare, should be targeted for inclusion	1) Include examples of all 23 EUNIS Level 3 broad-scale habitats in the network 2) Include examples of all listed rare and threatened habitats specified 3) Include examples of all listed rare and threatened species of low and high mobility	1) Include typical examples of each community and physical environment type (BOP 7) 2) Include biophysically special/unique places (BOP 9) 3) Represent cross-shelf and latitudinal diversity in the network of no-take zones (BOP 11)	1) Protect the full range of marine habitats and ecosystems 2) MPAs should be designated based on a consistent approach to classification of habitats and ecosystems 3) Represent latitudinal and longitudinal variation

Adequacy

Context and international case study application

A network of MPAs must be sufficient in size to sustain its ecological objectives in the long-term, which relies on the inclusion of an adequate proportion of each of the component habitats or features. The principle of 'adequacy' here refers to the overall amount of habitat included within a network of all MPA types and should not be confused with the proportion contained specifically within marine reserves (no-take zones), which is discussed in Part 2: Levels of Protection. Nevertheless, the adequacy principle is controversial in that it often results in the application of one or many percentage targets – either data-dependent or data-independent – for area coverage.

Targets clearly provide specific, measurable indicators of success that can be explicitly justified and objectively monitored within an adaptive management framework [5] and provide clear objectives for stakeholder-driven processes. Using ***data-independent targets*** has been discredited by several authors, as they are insensitive to different habitat requirements or species assemblages [21], overlook ecological processes or habitat-specific features [22] and provide a false sense of security [23].

Rondinini [24] appraised the strengths and weaknesses of different methodologies used to develop ***data-dependent targets*** (either marine or terrestrial) for habitat adequacy. He concluded that methods used to establish fixed targets across all habitats were simple to communicate, but scientifically unjustified, as they did not consider the variation in different habitats and their differing protection needs. He considered developing habitat-specific targets based on species-area curves [see 25] to be the most scientifically robust and defensible approach, but noted the requirement for high levels of analysis and habitat-specific data. When the large amounts of necessary data are absent, Rondinini considered developing heuristic 'rules of thumb' [see 26] to be a comprehensive and scientifically sound approach.

As a result of his review, Rondinini developed habitat-specific maximum and minimum numerical targets (between 10-40% coverage depending upon habitat) to represent the adequacy principle in the UK MPA network design guidelines [27], as developing species-area curves was considered the most scientifically robust method given the amount and nature of the available broad-scale habitat data. In terms of practical implementation, this method was successful in providing MCZ stakeholders with measurable, defensible and non-subjective goals, and these targets were met for the majority of habitats, although it required a great deal of staff analysis time to evaluate progress in meeting each of the separate targets.

In the GBRMP RAP process, habitat-specific adequacy targets of 20% for reef and non-reef bioregions were established by the Scientific Steering Committee [10,11]. However, since the GBRMP RAP rezoning established only no-take zones, the elaboration of percentage targets related only how much of each bioregion would be included within these no-take zones, rather than how much would be adequate within a network containing a range of protection levels. In sharp contrast to both the other case studies, the MLPA Initiative science guidelines did not include numerical targets for adequacy, but relied upon the presence of other specific network design principles (habitat representation and replication, MPA size and spacing) to deliver an ecologically sustainable network of MPAs [28]. This was an interesting departure from the planning process undertaken in the California Channel Islands just prior to the MLPA process (and included within it) that used fixed numerical targets of 30-50% of each habitat to deliver the network objectives [29]. In their summary of the MLPA Initiative process, Gleeson and colleagues [28] intimated that the removal of numerical adequacy targets was due to the criticism the fixed percentage approach received.

New Zealand context
The New Zealand MPA Policy was designed to help achieve the New Zealand Biodiversity Strategy target of protecting 10% of the marine environment by 2010 through a network of representative protected marine areas [30], as recommended by the Convention on Biological Diversity in 2005 (CBD 2005a). A recent gap analysis by the Department of Conservation [31] states that "the ultimate extent of protection will be determined by what coverage is required to establish a comprehensive and representative network of marine protected areas". While 10% is recognised as the target set out in the NZ Biodiversity Strategy, there is no explicit MPA Policy guideline providing a recommendation on the amount or proportion of area to be protected. Consequently, after extensive stakeholder engagement in MPA planning for the west coast of the South Island, only four marine reserves were proposed and these have been significantly reduced in size to protect, if approved, only 1% of that region in no-take zones.

Table 5. Adequacy

MLPA Initiative	UK MCZ Project	GBRMP Representative Areas Program	NZ MPA Process
None specified (Incorporated in design through guidelines on minimum size and maximum spacing of MPAs)	Specific percentage targets (minimum and maximum thresholds) given for each broad-scale habitat and feature of conservation importance	1) Represent at least 3 reefs and 20% of reef area and 20% of reef perimeter in each reef bioregion in no-take areas (NTAs) 2) Represent a minimum amount (20%) of each non-reef bioregion in NTAs, with specific habitats requiring special provisions	None specified

Viability

Context and international case study application

A viable network is considered to be ecologically self-sustaining in the long-term [7] with individual MPAs of sufficient size to allow most ecological processes to operate within them [32]. Viability can be evaluated either at the MPA level – the minimum size for an individual MPA to be self-sustaining – but also at the system level – the configurations of large and small sites within a network.

At the individual MPA level, a quantitative review of 89 studies on the effects of no take reserves on fish size, biomass, density and species richness demonstrated that reserve size was not critical to significant increases for all these metrics [33]. However, although very small reserves produced proportionally equal results to large reserves (e.g. a doubling in biomass), Halpern stressed that this did not necessarily make small reserves self sustaining or desirable for fisheries managers, since a doubling of numbers in a small site is a much smaller absolute increase than doubling in a large reserve. More recent studies have however demonstrated that small reserves have limited benefits in protecting exploited species [34,35]. Small MPAs may be expected to enhance larval export or exchange through their increased edge-to-area ratio, but more edges also means faster export of adults, which is unlikely to sustain populations large enough to persist long term [12,36]. While small reserves may achieve high densities of target species on a per area basis (i.e. transect level), Roberts and Hawkins (2000) point out that given the small geographic area the overall importance of the MPA for the wider population is likely to be negligible. Obviously, larger MPAs protect more fish and therefore have a greater potential to contribute to the wider larval pool.

For individual MPAs to support self-sustaining populations, they need to retain a given species within their boundaries throughout their lifecycle [4]. Given the long larval duration of most marine species this is not possible without very large reserves. Instead, individual reserves typically need to be large enough to encompass the home range of desired species and therefore viable size will depend upon the mobility of species identified for protection.

The Science Advisory Team for the MLPA Initiative investigated patterns in adult movement according to habitat preferences [17], The viability principle recommended MPAs should be between 5-10km but preferably 10-20km in coastline length for the MLPA Initiative. These distances were considered appropriate to encompass the home ranges of a large proportion of coastal species (Fig. 5, Saarman et al 2012), while also allowing populations of some short-dispersing species, such as abalone, to potentially be self-sustaining.

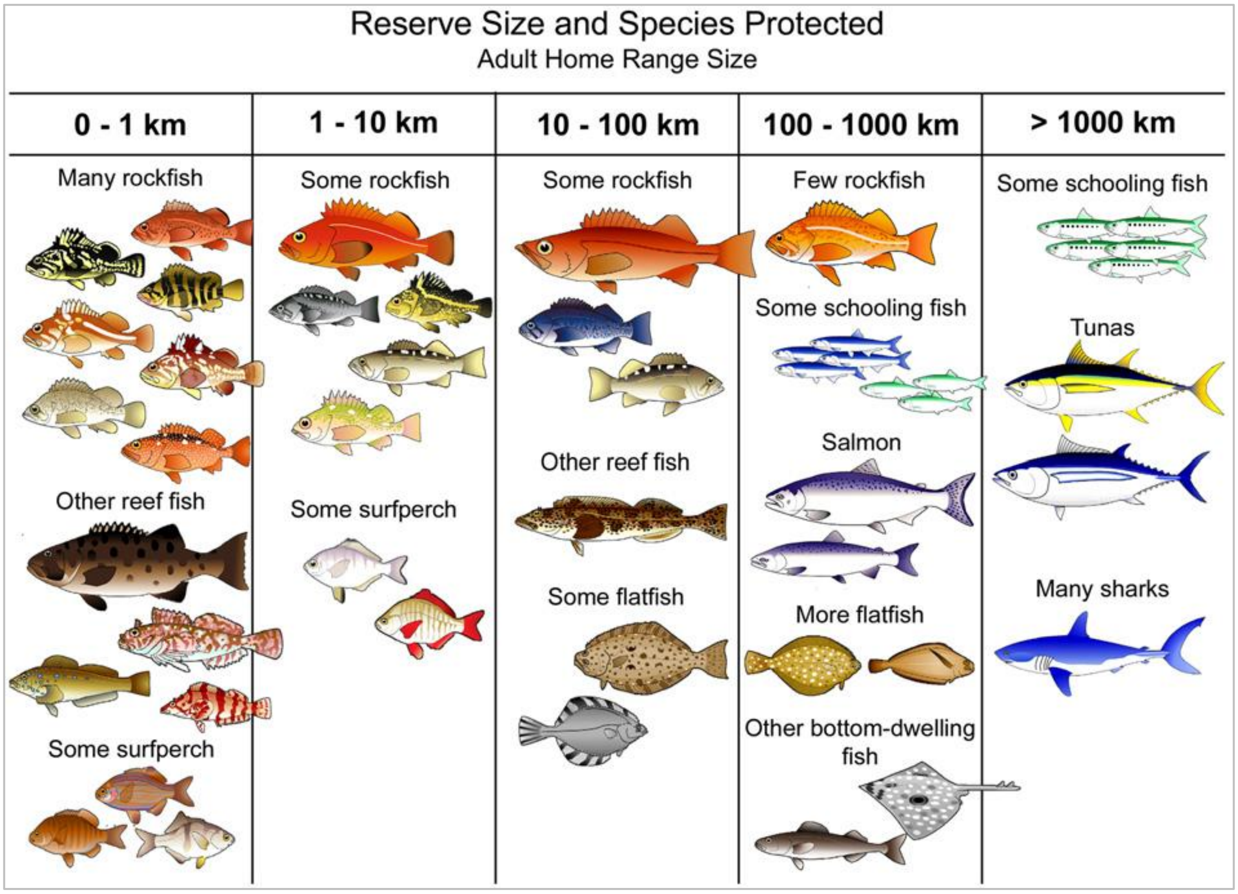

Figure 5. Reproduced from Saarman et al 2012: "A graphical representation of adult movement patterns of west coast fish species derived from a literature review. Each fish represents an individual species for which movements have been studied. Many fish species associated with rocky reef habitats exhibit home range movements of 10 km or less. Fish images courtesy of Larry Allen."

The MCZ Project reviewed adult movement information as well as researching life-history traits, physiology, and evolutionary origin [37]. The resulting guidelines for broad-scale habitats specified a 5km minimum dimension but an average of 10-20km By contrast, the GBRMP RAP Scientific Steering Committee specified a much larger minimum dimension of 20km. The MLPA Initiative included a requirement that sites extend from coastal, intertidal waters to deeper offshore waters, to ensure protection of the habitats used throughout the lifecycle of targeted species and thereby fixing a minimum width and length to all sites (the maximum distance from shore was limited to 3 nautical miles for the MLPA Initiative as this is the edge of State waters).

Factors other than ecological persistence such as management effectiveness, stakeholder support and compliance should also contribute to the viability debate at both the individual and system level. In inshore highly developed or populated areas, smaller sites would minimise the socio-economic impact on stakeholders, and may therefore be easier to set up and enforce. However, it is important that these "small" reserves remain of sufficient size to be viable (i.e. at or above minimum size requirements) in order for them to contribute to the greater network and play a role in biodiversity protection. The UK MCZ Project provided minimum patch sizes (e.g. 0.5km) for rare and threatened habitats and species within MPAs, but in combination with other guidelines, this unfortunately led to the recommendation of extremely small Reference Areas for individual habitats that were unlikely to provide effective protection. In some cases there may be a case for small MPAs below the recommended size for specific conservation purposes, such as protecting spawning grounds or sea bird and marine mammal breeding colonies. In offshore areas, MPAs that are small are harder to manage and enforce, as well as being harder for ships to accurately locate and avoid [36].

At the network level, viability refers to whether a few large sites perform better than several smaller ones. The GBRMP RAP recommended that fewer, larger areas be established rather than smaller ones, to avoid edge-effects [10], but neither the MCZ Project or the MLPA Initiative considered this question explicitly, although the minimum size and spacing guidelines suggested a preference for few larger reserves.

Roberts *et al.* [36] consider that within any given network of MPAs, there is no optimal MPA size and that to balance expected ecological, social and economic benefits a network design should have MPAs of varying sizes. When taking all network design principles into account together, however, Roberts *et al.* [37] noted that a tendency to select smaller-sized MPAs would require a greater number of MPAs overall in order to achieve representativity and connectivity, and thus recommended that fewer, larger MPAs were the preferred approach in order to avoid potential management and enforcement challenges. With hindsight, it may have been very useful for the UK MCZ Project to have undertaken a preliminary analysis to examine the likely outcomes of its viability principles, since the ultimate MCZ network recommendation reflected the prediction made by Roberts *et al.* and consisted of a very large number of sites (n=127), some as small as 0.5km in diameter.

Boundary configuration of individual MPAs is also critical in ensuring viability and is also important for MPA management (i.e. compliance). Ideally, boundaries need to be simple with low boundary length-to-area ratios in order to minimise edge effects and maximise the effective area of the MPA. The MLPA Initiative and the MCZ Project provided detailed guidance on how to set MPA boundaries to take into consideration issues such as capturing the feature of interest and using easily recognisable navigational aids and coordinates.

New Zealand context

The NZ MPA Policy & Implementation Plan suggests that MPAs should be of “sufficient size to provide for the maintenance of populations of plants and animals” and recommends that any efforts should “protect fewer, larger areas rather than numerous smaller areas”. This guideline of fewer larger MPAs is consistent with the other case studies but no numerical guidance is given on MPA size.

Recent research suggests that the minimum size requirements of no-take zones used in the international case studies (e.g., minimum coastline lengths of 5km and preferred of 10-20 km) would be appropriate in the New Zealand context. Babcock *et al.* [38] found that marine reserves with sizes of approximately 5 km^2 (i.e. 5km of coast with 1km distance to offshore boundary) were too small to fully protect resident reserve snapper populations. Therefore, while reserves spanning ~5km of coast are known to still have conservation benefits and result in increased biomasses of snapper [39], this size should be considered a minimum.

Table 6. Viability			
MLPA Initiative	**UK MCZ Project**	**GBRMP Representative Areas Program**	**NZ MPA Process**
1) 5-10km min (10-20km preferred) length 2) Must extend from intertidal to deeper offshore	1) MCZs for broad-scale habitats should have a minimum diameter of 5 km with the average size being between 10 and 20 km in diameter 2) Patches of habitats of conservation importance within MCZs should have a minimum diameter as specified (minimum patch size = 0.1km).	1) No-take areas (NTAs) should be at least 20 km long on the smallest dimension (except for coastal bioregions) 2) For a given amount of area to be protected, protect fewer, larger areas rather than smaller areas, particularly to minimise 'edge effects' resulting from use of the surrounding areas. 3) Where a reef is incorporated into NTAs, the whole reef should be included to avoid fragmentation	1) Protected areas may be of various shapes and sizes but should be of sufficient size to provide for the maintenance of populations of plants and animals. 2) Have fewer larger (versus numerous smaller) protected areas [Secondary consideration]

Replication

Context and international case study application

Ecological resilience is encouraged through the non-contiguous replication of adequately protected representative habitats within an MPA network. Ensuring that duplicate or multiple examples of each bio-geographical habitat type are included within an MPA network increases persistence of biodiversity in the long term by reducing the risk of catastrophic damage from environmental or anthropogenic disturbance storms or oil spills [7,12] or unexpected declines in population numbers [1,32].

Provided replicates are located to facilitate inter-connectivity, replicate MPAs therefore ensure that species can move between protected areas of suitable habitat or key lifecycle areas [1], which should increase the conservation and fisheries benefits of the network, beyond that of any single MPA. Multiple examples of each biological habitat also increase the chance of capturing samples of natural variation in biological communities [2]. Replicate examples also allow standardised comparison between similar MPAs, which provides the opportunity to analyse the cause of variation [4,7] and supports an adaptive approach to management.

There are other approaches to achieving resilience. Allison *et al*. [40] also looked at building resilience through the inclusion of an insurance factor that calculated the additional area of habitat required to withstand the likely occurrence of catastrophes, such as oil spills, hurricanes or combined events. The Convention on Biological Diversity Technical Guidance [32] states that, in addition to replication, resilience can be increased by ensuring that areas exhibiting specific characteristics associated with adaptability are included in MPAs (e.g. areas of high biodiversity, upwellings, areas on ecological boundaries).

The GBRMP RAP incorporated at least 3-4 replicates of each bioregion into no-take areas, with larger or smaller habitats requiring more or less replicates respectively [10]. With its objectives to support biodiversity and support the recovery of wildlife populations (including target fish species) the MLPA Initiative required 3-5 replicates of each key habitat, in order to provide robust analytical power for management decisions, buffer against risk of catastrophe and to protect against annual variations in larval production [18]. The UK MCZ Project recommended that at least two examples of broad scale habitats were protected and additionally, that 3-5 examples of the more rare and threatened habitats and species were included in the network [20]. However, without modelled distributions of the rare and threatened features or clarity on how to link these two guidance principles together in an ecologically meaningful way, the location of recommended MCZs was driven very strongly by the presence of rare species records alone, dramatically reducing the strength of the evidence base and political support for designation.

New Zealand context
The NZ MPA Policy and Implementation plan states under Network Design Principle 3 that the "number of replicate MPAs included in the network will usually be two. However, in circumstances where a habitat or ecosystem is particularly vulnerable to irreversible change, more replicates may be established as a national priority." This guideline is in contrast to the international case studies, which typically required at least 3 replicates.

Table 7. Replication

MLPA Initiative	UK MCZ Project	GBRMP Representative Areas Program	NZ MPA Process
3-5 examples of each habitat per biogeographic region	In each biogeographic region: 1) 2 examples of each EUNIS Level 3 broad-scale habitat 2) 3-5 examples of each key feature	1) Represent at least 3 reefs and 20% of reef area and 20% of reef perimeter in each reef bioregion in no-take areas 2) For most bioregions, 3–4 NTAs are recommended. For some very small bioregions fewer areas are recommended, whilst for some very large or long bioregions, more no-take areas are recommended.	Consideration should be given to whether the site provides replication of habitats and ecosystems in a biogeographic region. [Secondary consideration]

Connectivity

Context and international case study application

Although individual, independent MPAs are a valuable tool for biodiversity conservation and fisheries management, MPA networks should deliver far greater benefits due to the ecological linkages between sites and the greater spatial scales involved. Connectivity aims to maximise the ecological linkages between sites within an MPA network, such that the overall benefits of the MPA network far exceed the summed benefits of the individual MPAs. This fundamentally requires the exchange of eggs, larvae, juveniles and adults among MPAs with the aim of maintaining species populations in the long term across all parts of their range [32].

Achieving connectivity is a challenging goal, as it requires an understanding of larval dispersal patterns, adult and juvenile mobility, distribution of key habitats, and oceanographic characteristics (e.g. currents, upwellings). Effective connectivity is also highly dependent upon the size of individual reserves that protect the population, as ideally they need to be big enough to retain some larval recruits and therefore be self-sustaining (particularly for short dispersers), but also small enough and sufficiently well connected to each other to facilitate spill-over and exchange of larvae to replenish other populations and surrounding fishing grounds [41].

Despite its critical importance, Gaines *et al.* [42] found that few theoretical models exploring the effects of reserve design incorporated the complexities of larval dispersal explicitly, particularly the role of ocean currents in delivering flow-generated connectivity. Through modelling the effect of advection on larval dispersal, Gaines *et al.* suggested that taking ocean current patterns into account in reserve design could significantly enhance connectivity and therefore fisheries benefits.

In reality, larval dispersal patterns and adult movement distances vary hugely between species and will be affected by changing ocean conditions, so any connectivity reserve design must attempt to maximize the possibilities for larval and individual exchange between the widest range of species [7]. To achieve this, MPAs need to be spaced in a fashion (i.e. close enough to each other) that larvae from the large majority of species can disperse from one MPA to the next.

Using genetic data for common dispersal distances for marine invertebrates and fish species [43,44], the connectivity principle for the MLPA Initiative required reserves to be sited within 50-100km of each other, in order to be within the dispersal range of most commercial or recreational groundfish or invertebrate species [18].

When advising the UK MCZ Project on connectivity, Roberts *et al.* [37] looked at the genetic evidence (e.g. Kinlan, S. D. Gaines, and Lester 2005; Kinlan and S. D. Gaines 2003) but also examined data from theoretical models of larval propagule dispersal [45], measured export of larvae from MPAs [46], the spread of invasive species [47] and other approaches (e.g. distance between spawning and nursery grounds) to predict the likely dispersal distances of UK marine organisms. However, Roberts *et al.* (2010) also argued that delivery of ecological connectivity would be strongly influenced by habitat specificity and levels of protection. Dispersing larvae are only likely to survive if they find suitable habitats in which to settle and MPA spacing should therefore be habitat specific. Furthermore, highly protected MPAs that reduce fishing serve to increase the reproductive output within them (e.g. more reproductively successful individuals) and therefore potentially increase the distances that individuals from those populations are likely to cover.

In its scientific guidance, the MCZ Project's connectivity principle encouraged the use of species-specific dispersal distances to determine MPA spacing (if they were known), but otherwise recommended that *similar habitats* inside MPAs to occur within 40-80km of each other (though in practice, 'similar habitats' were described at a very broad-scale level) [20].

New Zealand context
The NZ MPA Process documentation recognises the importance of maximising connectivity in designing MPA networks but does not provide guidelines on how this might be achieved. As seen in the MLPA and UK MCZ project this connectivity principle can be incorporated into MPA planning with a simple spacing guideline that gives recommended maximum distances between MPAs.

Table 8. Connectivity

MLPA Initiative	UK MCZ Project	GBRMP Representative Areas Program	NZ MPA Process
1) Sites should be separated by 50-100km	1) Known species-specific dispersal distances or critical areas for life-cycles of listed species should be used to determine the spacing between MPAs 2) MPAs of similar habitats should be separated, where possible, by no more than 40 – 80 km 3) Connectivity may be approximated by ensuring that MPAs are well distributed across the regional MCZ project areas	1) Avoid fragmentation - Where a reef is incorporated into a site, the whole reef should be included	1) Maximise connectivity – the design of the protected area network should seek to maximise and enhance the linkages among individual protected areas, groups of protected areas within a given biogeographic region, and across biogeographic regions.

Best available evidence

Context and international case study application
This was an explicit and highly significant guideline for all three MPA network design processes. Primarily, this recommendation ensures that networks are designed using what is currently known about the necessary biological and ecological processes, such as migration patterns, species assemblages and connectivity, incorporating various forms of information in ways that can be useful for planning and capturing important local knowledge [10,18,20].

Equally important is the principle that gaps in data, perceptions relating to the quality of data or the possibility of obtaining improved data should not delay the process of designing the MPA network, which could make the process more costly and result in the degradation of important features. Measures to protect vulnerable habitats and improve resource management should be implemented as soon as possible, using the highest quality data that is available at any given time, using an adaptive management approach that allows for sites to be monitored and adjusted in the future if objectives are not being met.

Although this guideline was listed as one of the seven major principles for the UK MCZ Project and instigated a very large data-gathering exercise, inadequacy of data was given as the main reason why the UK Government Minister chose to delay designation of MCZ sites [48], a source of considerable controversy. To avoid this disappointing situation, it would be sensible to combine the 'best available data' principle with clear guidance on the depth of information, data sources and types of data manipulation that might be questioned (e.g. grey literature, historical records, modelling species distribution on sparse data points), as well as the levels of evidence that would be necessary to support the recommendation of a site (e.g. at least one fine-scale, ground-truthed habitat map source).

New Zealand context
The NZ MPA Process Planning Principle 7 states that "Best available information will be taken into account in decision-making."

Additional considerations

Although the major ecological design principles shared by all three case studies were fairly simple to identify at the generic level, there were other ecological network design considerations that were given different levels of priority across the three processes.

Ecosystem Services
Ecosystems services can be described as the beneficial services that humans receive from ecosystem functions [49]. As studies advance in understanding ecosystem services, our appreciation of their value grows. Key services such as fisheries, environmental resilience, pollution control and tourism are all delivered by ecosystem functions such as primary productivity, larval supply and trophic web dynamics. These beneficial ecosystem functions should be protected wherever possible to ensure the sustainability of our resources, such as food, raw materials, and societal well-being, and to build resilience against the impacts of climate change [50]. However, ecosystem service quantification and valuation is still in its infancy and the quality of available data and surrounding uncertainties may present significant challenges to MPA network planning processes. At present, capturing ecosystem pattern (i.e. habitats) and processes (i.e. spawning/nursery grounds) is probably, a more valid approach to network design than attempting to incorporate the science of ecosystem service valuation in its early development.

Although ecosystem services were not explicitly described as conservation targets within the case studies examined here, many of the important ecosystem processes that underpin the most valuable ecosystem services were identified for incorporation within the networks through the major design principles (e.g. the connectivity and viability guidelines are based upon larval dispersal distances). In the MLPA initiative, upwellings, freshwater plumes and larval retention centres were included as 'key habitats' that needed representation within the network, and areas of particular productivity (e.g. kelp forests) were recommended for special consideration [18]. Similarly, the viability principle required all sites to extend from shallow inshore to deeper offshore areas in order to maintain movement between spawning grounds.

In both the UK MCZ Project and the GBRMP RAP, ecosystem processes were also captured within the connectivity and viability principles, but, like the MLPA Initiative, the UK MCZ Project also identified areas that play significant roles in key lifecycle stages (e.g. spawning and nursery grounds, migratory pathways) and sites of high biodiversity or productivity (called Areas of Additional Ecological Importance) for additional consideration within the network [20]. However, since these areas were not considered as 'key habitats' and were therefore not expressly listed for representation within the network (i.e. they were a secondary consideration), their inclusion in MPA recommendations was not as prominent as the key habitats themselves.

The GBRMP RAP appeared to give less consideration to ecosystem processes through its guidelines, as the connectivity principle was not described through larval dispersal. The Biophysical Operating Principles included 'biophysically special or unique places' to ensure the capture of outstanding places necessary for the maintenance of biodiversity [51], but upwellings and high productivity were not apparently given deliberate consideration.

New Zealand context
Specific provision for protecting ecosystem services is not incorporated into the NZ MPA Process although provision is made to protect New Zealand's natural marine habitats and ecosystems in a "healthy functioning state". An additional consideration involves taking into account obligations that arise from Treaty of Waitangi commitments to tangata whenua, by providing for "the special relationship between the Crown and Maori, including kaitiakitanga, customary use and mätauranga Maori".

Recommendations for the New Zealand MPA Process

In the NZ MPA Process there are a number of principles and guidelines provided [52,53]. As their name suggests, guidelines are recommendations for network design and are not prescriptive. However, where the network design process involves stakeholder groups, often with differing objectives, the use of specific, science-based numeric targets is the most efficient and effective way to produce MPA recommendations, as they can be justified and measured. When comparing the NZ MPA Process to the clear guidelines developed by all three case studies, it is clear that the NZ guidelines are not numeric or particularly specific. We believe that simple, yet highly specific and scientifically justifiable guidelines contributed to the successful delivery of these planning processes, primarily because stakeholders had clear "instructions" with which to design reserves and managers had clear measures with which to evaluate the conservation value of proposed networks.

There are strong parallels and considerable overlap in the ecological design guidelines used in the three case studies reviewed in this report. This is largely due to the fact that they are all based on the best available science from around the world at the time (including research from New Zealand MPAs), and also because there are strong functional similarities between the three systems. New Zealand marine ecosystems have a number of functionally analogous species and ecosystems to those found in the other systems, particularly with California. Therefore, we can be confident that recommendations from these case study guidelines should support the NZ process in delivering an ecologically comprehensive and coherent network of MPAs that delivers protection for long-term biodiversity persistence.

Consequently, we propose that subsequent guidance developed for the NZ MPA Process follows these recommendations:

- **All habitats are represented in the network.** The appropriate habitat classification should match the spatial scale of the conservation planning efforts and at fine scales should result in the definition of common rather than unique habitats. Ecosystem processes (e.g. important areas for biodiversity, productivity and species life cycle events) should be represented. This guidance appears in the NZ documentation and both an appropriate habitat classification process and a gap analysis have been proposed.

- **Enough of each specific habitat should be included in the network to be functionally protected**. If sufficient biodiversity data permit, habitat-specific targets would be recommended (following a species-area curve calculation to ensure protection of a clear majority of species found in each habitat). In the absence of such data, we would recommend rigorous application of other scientifically robust design principles (e.g. viability, connectivity and representativity), as demonstrated by the MLPA Initiative. However, this latter approach was arguably only successful because of the transparent establishment of measures of the level of protection during the planning process with stakeholders (See Chapter 2, Part 2) and therefore any transfer of this approach to the NZ process should ensure protection measures are considered at the same time as the design principles. The NZ MPA Policy highlights the use of a 'protection standard', which is an encouraging sign that levels of adequate protection are likely to be considered as a critical part of the MPA network design process.

- **MPAs should be large enough to cover the majority of species adult movement distances**. Based on these case studies and extensive studies from existing New Zealand reserves, we would recommend that MPAs have a minimum coastline length of 5-10 km, preferably 10-20 km, and should extend along the depth gradient from intertidal to deeper offshore waters, preferably to the 12 nautical mile limit.

- **Several examples of each habitat should be included within separated MPAs**. Looking at the case studies, we would recommend that a precautionary number of replicates would be 3, with two replicates being the bare minimum. Replicates are more effective if they are habitat-based to avoid single records driving the design.

- **The spacing between MPAs should allow larval dispersal to occur.** Numerous factors influence successful connectivity (hydrodynamics, suitable habitat distribution, MPA size and protection levels) and therefore guidelines are likely to be predictions and rules of thumb. We recommend that MPAs, with similar habitats where possible, should be placed within 50-100 km of each other.

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PART II: Levels of protection in MPA networks

The level of protection afforded to a MPA defines the MPA status or type (e.g. 'marine reserve') and the varying activities that are managed or restricted within its boundaries, potentially ranging from multiple uses to no-take and even no-entry zones. In this section, we examine the rationale for including MPAs of differing levels of protection within an MPA network and summarise the literature describing the ecological effects of these different MPA types. We then look at what has been suggested as an appropriate proportion of any network that should be contained in no-take zones.

Highly protected MPAs that restrict all extractive activities are typically termed 'No-take zones' (NTZs) or "Marine reserves", and a wide variety of names are used to describe MPAs that allow certain activities, such as "conservation areas", "marine parks" etc. The level of protection required and the type of MPA implemented in a particular area is clearly dependent on the goals of the MPA design process and also the level of activities that already occur in an area.

As there is a long and varied history of extractive uses in most coastal areas, no-take zones are often contentious. However, if the goal of the MPA process is biodiversity protection and long-term persistence, then it is essential that any permitted activities do not compromise this goal. Due to the complexity and inter-connectedness of foodwebs and ecosystems, removal of particular components (i.e. target species) may indirectly impact on other components of the ecosystem, affecting its biodiversity. Since the direct and indirect impacts of various activities on ecosystems are often uncertain, ensuring biodiversity protection requires the precautionary approach through establishing NTZs that eliminate real and potential threats from human activities within, or even adjacent to, an MPA.

Processes that have established MPA networks over large spatial scales typically have no-take zones at their core and over time these have begun to demonstrate successful progress as a result [1]. However, these MPA networks also contain a variety of other MPAs that restrict or manage activities as necessary. These partially protected multiple-use MPAs can play an important role in protecting sensitive habitats and benthic ecosystems against particularly destructive fishing practices, such as trawling. Establishing these MPA types and the activity restrictions should be part of the network design itself, and the process by which this is achieved may have a significant impact on the overall support for the network and therefore its likely ecological success. It is important to note that identifying '*levels of protection*' describes a process for agreeing the appropriate management measures necessary to deliver an MPA's ecological objectives, which is not the same as achieving *management effectiveness* once the MPA is in place (e.g. strong compliance with regulations and control of illegal activities). Both are essential for successful marine protection to occur.

Ecological effects of different types of MPAs

Research into the effectiveness of MPAs has largely focussed on no-take zones or marine reserves and there is considerable literature on their value in protecting biodiversity [See meta-analysis by 2]. Because marine reserves restrict all activities, numerous case studies of individual reserves demonstrate that they allow recovery of both species and habitats at all depths which therefore promotes increased population growth, provides shelter for vulnerable species, maintains biodiversity and strengthens ecosystem resilience to climate change and catastrophe [1]. In their meta-analysis of 149 no-take marine reserves from 29 countries, Lester et al. [2] confirm previous findings that suggest no take reserves result in statistically significant increases in biomass, density, number and species richness, though not necessarily for all taxonomic groups. Temperate no-take reserves were found to show similar, or even increased, positive biological responses compared with tropical ones, though this conclusion can only be drawn for reef habitats, given the lack of comparative marine reserve data for other habitat types.

Despite the considerable biological evidence supporting no-take zone efficacy, the practice of limiting all activities remains unpalatable to those who feel that certain fishing activities are not a significant threat to biodiversity and ecosystems [e.g. 3]. Although there are fewer studies which investigate the relative effectiveness of MPAs allowing different levels of protection, such studies still demonstrate that partially protected MPAs (allowing certain types of fishing) have limited conservation benefits compared to no-take zones [4–6]. This is explained by a number of reasons. Firstly, even relatively low levels of fishing pressure can suppress many populations and prevent recovery, and secondly, fishing methods that are allowed to continue in an MPA effectively "take up the slack" in terms of catching the fish that may have been caught by the prohibited methods. Furthermore, increasing evidence suggests that partial protection can concentrate fishing efforts towards particular target species, thus increasing the likely impact [4].

In northern New Zealand, comparisons have been made between coastal marine reserves (no-take), marine parks (allowing recreational fishing) and fully fished/open access areas [7,8]. These studies found that the density and size of both reef fish (including snapper) and lobster were comparable between the open access areas and the marine parks, concluding that in coastal areas where recreational fishing effort is high there is no conservation value in protecting against commercial fishing alone. By contrast, the no-take zones in both studies contained targeted species that were considerably larger and more abundant, a pattern that has been demonstrated worldwide [2].

Proportion of habitat within no-take zones

Any recommended proportion of NTZs within a network is likely to be driven by specific network goals, spatial area, sensitive habitats and levels of human activity. To catalyse global efforts, the World Parks Congress set a target in 2003 to include 20-30% of each habitat within strictly protected areas [9]. For biodiversity protection, Ballantine [10] suggested 10% of New Zealand's coastal environment should be protected in no-take zones, while Bohnsack [11] argued that 20-30% in no-take zones was precautionary for coral reef ecosystems [for review, see 12]. Studies have estimated that highly protected areas aimed at improving fishing catch sizes should capture 20-40% of the fished area, but the range expands to 20-50% when these are designed to reduce the risk of overexploitation [see 1 for a review] and other reviews have suggested much higher proportions (35-75%) [in 12,13]. In their review, Roberts and Hawkins [1] highlight the very different reasons for setting targets – fisheries yields, risk management, ethics, conservation or connectivity - but agree that targets tend to converge around 20-40% to deliver maximum benefits in the face of uncertainty.

It is worth noting that most of the aforementioned targets were not recommended as a proportion of a larger network of multiple use MPAs. In this context of MPA network design, the question is two-fold: firstly, how much habitat should be protected in the network, and secondly, how much of the network should be within highly protected areas rather than multiple use? We have addressed the first question within the adequacy guidelines (see Part 1: Ecological design guidelines). In answer to the second question, the California Channel Islands required 30-50% of its network to be protected within marine reserves and the GBRMP Representative Areas program included at least 20% of reef and non-reef bioregions within no-take zones.

Neither the UK MCZ Project nor the California MLPA Initiative adopted targets for NTZs. In slightly different approaches, both processes established very clear ecological design guidelines for replication, viability and connectivity and applied these to the guidance on levels of protection, which would automatically establish a proportion of NTZs within their respective networks without having a predetermined target. As we have described below, this approach and its added benefits worked sufficiently well for the MLPA Initiative that it would arguably be preferable to target setting. However, it did not work effectively for the UK MCZ Project and we have suggested reasons why this may be so.

The reviewed case studies all incorporated both highly protected MPAs and partially protected MPAs within their design guidelines to varying extents. How this was done and the outcome of the process is summarized for each case study below.

Case Studies:

Great Barrier Reef Marine Park

<u>MPA types</u>

The original GBRMP plan created seven main types of MPAs it called 'zones', provided for increasing levels of protection and various types of resource use, covering the spectrum from general use to completely no-take and no entry. Three of the seven zones are no-take, though two of these zones permit some traditional uses to occur.

<u>Mandate in regard to MPA types</u>

The Great Barrier Reef Marine Park Act 1975 makes provision for a zoning plan to facilitate "reasonable use" of the Marine Park, as well as requiring that it "protect areas in the Marine Park that are of high conservation value; and protect and conserve the biodiversity of the Marine Park, including ecosystems, habitats, populations and genes". In order to achieve this mandate, and to meet Australia's other international commitments to protect biodiversity (e.g. Australia's Ocean Policy), both the original zoning plan and the RAP included highly protected areas (Marine National Park Zones, Preservation Zones and Scientific Research Zones) justified by the GBRMP Authority through scientific evidence supporting the value of no-take zones.

To achieve the objectives of the RAP, which was focused exclusively on expanding NTZ coverage, clear Biophysical Operational Principles (BOPs) were recommended by the Scientific Steering Committee, with input from other experts, to guide the establishment of a new representative network of no-take areas [14].

<u>Methods</u>

The RAP rezoning was highly participative in its nature and required an extensive communications strategy and two formal public consultations during which individual MPA recommendations were submitted and then incorporated into a draft zoning plan. From the outset, the RAP was designed to expand the network of no-take zones according to the associated ecological principles (see Part I). Although the process was controversial, the management measures and governance of any recommended sites was clear to stakeholders.

<u>Outcome</u>

In 2004, the proportion of the GBRMP protected by 'no-take' zones was increased from less than 5% to more than 33%, and now protects representative and replicated examples of each of the broad habitat types. The average size of a no-take area increased 5 times to 700 km^2 and the overall network now contains a minimum amount of each bioregion: reef bioregion percentages range from 20% to 47% and non-reef bioregion percentages range from 20% to >90% [14]. The overall percentage coverage of each zone is presented in Table 9 below:

Table 9: GBRMP Zone definitions, areas, restrictions and objectives reproduced from [15]

Type	% Area	Governance	Zone objectives during the Representative Areas Program (RAP)
Preservation Zone	0.3	**No-take**, no entry	For biologically significant populations of protected species; to preserve some areas of the GBR in its natural state undisturbed by man
Marine National Park Zone	**32.3**	**No-take** (some traditional use permitted)	For protecting representative habitats and species following the Biophysical Operating Principles designed for the RAP
Scientific Research Zone	0.1	**No-take** (some traditional use permitted)	For maintaining areas previously zoned as SRZs; and the waters adjacent to the six major research institutions in the Marine Park
Buffer Zone	3.8	Only trolling	For areas important for trolling for pelagic species around reefs or waters that are MNPZ or PZ, to provide for future conservation in areas where there are presently few activities
Conservation Park Zone	1.8	Restricted fishing (recreational)	For protecting waters adjacent to nationally/internationally important wetlands/conservation areas, areas previously zoned as CPZ but not identified as potential no-take zones, places of public access and areas of high recreational use
Habitat Protection Zone	**31.5**	No trawling	For existing HPZs not identified as a potential CPZ, SRZ, BZ or MNPZ, or a buffer around all islands and reefs in order to achieve the HPZ objective of 'ecologically sustainable use, including fishing'. Trawling should generally not occur any closer than 500m from all reefs and islands and thus this guideline avoids associated impacts of trawling in these areas
General Use Zone	**31.0**	General use	For areas not meeting other zone guidelines; and areas important for trawling or shipping which were not within 500m of a reef or island

Ecological outcomes

McCook *et al.* [5] found compelling evidence using various methods to suggest that GBRMP no-take zones benefit fish populations. Compared with fished zones, monitoring detected a doubling of number, size and biomass of commercially targeted coral trout inside no-take zones within two years of the re-zoning, and similar effects for other target species. Less obvious trends in fish number increases also held true in no-take zones for reef habitats in deeper waters, both in-shore and offshore. However, the differential in numbers was most dramatic in 'no-go' reserves, suggesting that non-compliance may well be the reason why the effect is less strong in no-take reserves. This tiered effect on increasing fish numbers in fished, no-take and no-entry zones respectively was also seen in shark species (refs from [5]. This provides one of the very few empirical comparisons between the effects of different MPA types and is strong evidence for the importance of marine reserves (no-take and no-entry) in delivering the successful ecological objectives in MPA networks.

Given the greater size, age and therefore increased larval output of target fish in the GBRMP, and the connectivity established between no-take reserves during the careful re-zoning, it is highly likely that the GBRMP no-take zones provide substantial larval supply across the entire network, including fished areas. Using genetic parentage analysis to explore patterns of larval dispersal for two species of exploited coral reef fish within a network of no-take marine reserves on the Great Barrier Reef, Harrison et al. [16] found that populations resident in three reserves exported 83% (coral trout, *Plectropomus maculatus*) and 55% (stripey snapper, *Lutjanus carponotatus*) of assigned offspring to fished reefs, with the remainder having recruited to natal reserves or other reserves in the region. Overall, they estimated that the no-take zones (28% of the local reef area surveyed) produced approximately half of all juvenile recruitment to both reserve and fished reefs within 30 km.

The California MLPA Process

MPA types

Three types of MPA designations were used in California: State Marine Reserves (fully protected no-take areas), State Marine Parks (where some recreational take may be allowed but commercial take is not allowed), and State Marine Conservation Areas (where some recreational and/or commercial take may be allowed) [17].

Mandate in regard to MPA types

The Marine Life Protection Act states that "Marine life reserves [defined as no-take] are an essential element of an MPA system because they protect habitat and ecosystems, conserve biological diversity, provide a sanctuary for fish and other sea life, enhance recreational and educational opportunities, provide a reference point against which scientists can measure changes elsewhere in the marine environment, and may help rebuild depleted fisheries." Consequently, the MLPA required a core of no-take zones as a critical component of the statewide network [17].

Methods

During the stakeholder group meetings, MPAs were recommended according the ecological principles (see Part I), along with their boundary shapes and the activities that would be permitted within them. These proposals were evaluated by the Science Advisory Team, which assigned levels of protection based on a simple conceptual model of species interactions and the potential impacts that permitted activities might have upon the species and habitats to be protected, as well as the interaction between species [18]. The conceptual model contained a series of questions, the results of which allowed MPAs to be given one of five levels of protection ranging from low to high. The MLPA Initiative (the overall decision-making team with Science Advisory Team advice) decided that MPA recommendations offering 'moderate-high' or 'high' levels of protection were sufficient to fulfill the aims and objectives of the MLPA itself. During the planning phase with stakeholders, the conceptual model was custom-built into MarineMap, the decision support tool that was used to provide stakeholders with immediate feedback on how their MPA recommendations met science guidelines, including levels of protection [19].

Outcome

The newly redesigned statewide network in California includes a total of 124 MPAs protecting 16% of state waters and comprises 37 State Marine Reserves and 69 State Marine Conservation Areas [20]. Of these MPAs, 61 are designated as no-take, covering 9.4% of state waters. A further 17 (2.7%) allow extraction of some marine resources, but are still considered to offer a high level of ecosystem protection that is sufficient to contribute toward the ecological goals of the MLPA. The remaining 46 MPAs in the statewide network (~4%) offer less protection to ecosystems and are therefore unlikely to contribute substantially to the ecological goals of the MLPA due to the types of allowed fishing activities. However, these MPAs are intended to contribute to the other goals (e.g. recreation) [20].

In general, the commercial and recreational activities permitted within State Marine Conservation Areas are primarily considered to have low ecological impact and, in the case of commercial species, predominantly target highly transient species such as squid and pelagic finfish, with no destructive fishing activities (such as trawling) allowed.

Ecological outcomes

Having only just been completed in 2012, it is too early to explore the statewide implications and ecological effects of the California MPA network. However, numerous studies from the Channel Islands Marine Reserve Network, which was established in 2003, have now been published, demonstrating the ecological effects of these reserves. Within the no-take zones there has been an increase in size and abundance of numerous targeted reef fish species [21] as well as spiny lobster [22,23]. There has also been a network-wide increase in the densities of exploited sea cucumbers within the no-take MPAs (Shears and Kushner unpubl. data). Studies from an older no-take reserve at the Channel Islands have also demonstrated that the size and biomass of exploited sea urchins is considerably larger than at fished sites [24]

To our knowledge no comparisons of the efficacy of different MPA types have been carried out in California.

The UK Marine Conservation Zones Project

MPA types

The UK MCZ project provided for the creation of a new type of MPA designation: Marine Conservation Zones (MCZs), one highly protected example of which was termed a 'Reference Area' (RAs). The new nationally important MCZs would be complementary to the existing MPA types: Special Areas of Conservation (SACs); Specially Protected Areas (SPAs); Sites of Special Scientific Interest (SSSIs) and Ramsar Sites.

In sharp contrast to other case study processes, UK site designations do not have any pre-determined restrictions associated with them and the governance or management of these sites is determined by the identification of activities deemed to damage or disturb the specific features listed for protection.

MPA Mandate in regard to MPA types

The 2009 Marine and Coastal Access Act supported the creation of Marine Conservation Zones to form an 'ecologically coherent network of MPAs' for conserving marine flora or fauna, marine habitats or types of marine habitat and features of geological or geomorphological interest. The MCZ Ecological Network Guidance[25] called for MCZs to have a range of protection levels, including at least one very highly protected MCZ for each habitat or feature of importance – to be called a 'Reference Area' – where no extractive, depositional or damaging activities would be permitted. However, there was also strong Government advocacy for minimizing the socio-economic impact of MCZs to sea-users. As with all UK MPAs, UK Government policy for establishing MCZ levels of protection requires the evaluation of sites on a case-by case basis, depending upon the features for protection within the sites, their vulnerability to potentially damaging activities and the level of exposure to those activities. Therefore, MPA protection levels (e.g. sites characterized by specific activity restrictions) could not be pre-determined and the term 'levels of protection' referred to the highly variable levels of activity restrictions or 'management measures' that could be applied to a site depending upon its characteristics.

Methods

During the stakeholder group meetings, the features for protection were first identified according to the ecological principles (see Part I) and appropriate site boundaries were established around them. At three stages during the process, the Science Advisory Panel of scientists evaluated the extent to which the network met the Ecological Network Guidance principles. However, since the UK process of identifying site-by-site protection levels was too data demanding and time-consuming for the stakeholder groups to feasibly undertake, final stakeholder MCZ recommendations had no management measures associated with them and were inevitably put forward with strong assumptions about potential activity restrictions.

Outcome

The UK MCZ process is not yet complete. Final stakeholder recommendations for 127 MCZs and 65 Reference Areas (some RAs occurred entirely within MCZs) were submitted to the

Government in 2011. However, these recommendations were sometimes submitted with strong caveats associated with them, suggesting that support would be withdrawn by various sectors if restrictions on their activities were subsequently imposed after site designation. Subsequent to submission of the recommendations, the UK Government declared that it would designate MCZs in a staggered series of 'tranches', aiming to designate the first 31 MCZs in 2013, although none of these will be highly protected Reference Areas. After site designation, the levels of protection associated with each MCZ will be determined.

Ecological Outcome

Since the UK process is not yet complete to designation stage, it will not yet be possible to evaluate the ecological success of these areas. Stakeholders recommended 15% of England's EEZ to be protected within 127 MCZs and approximately 1.9% in 65 Reference Areas (NTZs), but initial Government feedback suggests that the entire network is unlikely to be designated. Public consultation has been sought for the first set of only 31 MCZs (and no NTZs). If this first set is designated, the area likely to receive partial protection in multiple use MPAs would be 10,524 km^2.

Conclusions

In both the GBRMP RAP and California MLPA Initiative the focus was on incorporating substantial sites offering a high level of protection in order to achieve broad conservation goals. In both cases, a variety of MPA types were available, and a small proportion of MPAs (~5%) were established that allowed a variety of low impact recreational and commercial uses (e.g. Buffer Zones or Conservation Park Zones in GBR and SMCAs in California). However, due to **strong policy and scientific support for higher protection levels** to achieve conservation goals, a significant proportion of the MPAs established were no-take zones (GBR 33% and California 9%). In the GBRMP a large proportion of area (32%) was also set aside as Habitat Protection Zones where trawling is prohibited.

The GBRMP set a minimum threshold of 20% of each bioregion to be protected within no-take zones, but successfully managed to exceed that threshold by also requiring all other design guidelines (size, replication, connectivity) be met, ultimately designating 32.7% of the GBRMP as no-take.

By contrast, the California MLPA set no minimum threshold or any specific design guidelines for no-take zones, yet designated 9% state waters (58% of its total MPA coverage) in no-take zones. This was done through clear legal and policy demands for effective biodiversity conservation, which were translated by the Science Advisory Team as requiring high levels of protection in practice. In addition, very strong communication between the stakeholders and the Science Advisory Team, as well as powerful decision support technology and a relatively simple methodology, meant that stakeholders were given immediate feedback on whether their MPA designs (including activity restrictions) would provide the necessary protection to achieve the MLPA's ecological objectives.

Although the MCZ process had clear ecological guidelines that specified the delivery of science-based MPAs with a range of protection levels, the process to date has not succeeded in identifying the necessary levels of protection for sites or establishing highly protected sites. This is arguably due to the threat-based process for levels of protection for recommended sites. Although the UK Policy is a commendable attempt to make the management of MPAs specific to the threats that occur in each site, the process is heavily dependent upon a complex process requiring evidence to show feature distribution, level of exposure to activities and the damaging effect of those activities on that specific feature. Gathering this body of evidence is hugely time consuming and costly, but since ultimately the data are often sparse and rarely gathered from the exact site/feature/activity combination in question, competent authority experts are required to assess and decide the specific levels of protection required, leaving stakeholders excluded from critical information and decisions that might seriously affect their livelihoods and would certainly affect their MCZ recommendations.

In the UK MCZ situation, this resulted in a loss of stakeholder support for the process and the outcomes, which may affect compliance after site designation. Moreover, the strong evidence requirement made it difficult to apply the precautionary principle, as any establishment of management measures without strong supporting data could be justifiably contested by the stakeholder sectors likely to be impacted.

Interestingly, Kearney *et al.* [3] have strongly criticised the recent Australian National Representative System for Marine Protected Areas (NRSMPA) for not taking a threat-based approach to establishing levels of protection, which they imply would have allowed many forms of 'sustainable or environmentally benign' fishing to take place. Although site-specific assessment of threats is a pragmatic approach to identifying the appropriate management for an MPA network, the significant challenges of this approach should not be underestimated, since they could negatively affect the overall outcome in the ways demonstrated by the UK MCZ process.

Although both the MLPA Initiative and the UK MCZ Project attempted to identify levels of protection based upon site-specific threats, only the MLPA Initiative was successful in achieving this with stakeholder group support, scientific endorsement and prior to designation. Key to this success were some important factors that were unfortunately absent in the UK MCZ Project, such as the development of a scientifically-robust yet stakeholder-friendly conceptual model of activity impacts on ecological features, the strong stakeholder/Science Advisory Team interaction to validate suggested site protection levels, and the custom-built spatial planning decision support software to provide real-time evaluation of stakeholder site recommendations (ecological components and levels of protection) against the MLPA science guidelines. Without these elements in place, appropriate levels of protection can still be established, as demonstrated by the GBRMP RAP use of simple but effective targets for no-take zones.

Recommendations for the New Zealand MPA Process

By evaluating the practical and, where possible, ecological outcomes of these three MPA network design processes, we would recommend:

1) **No-take zones are considered a critical part of any MPA network design** for the following reasons:

a) ***Maximum conservation benefits*** – No-take zones ensure a high level of biodiversity protection, for habitats and species, as well as structure and function, and therefore form an integral part of an ecosystem approach to resource management and biodiversity conservation. They remove uncertainty (other than that created by non-compliance) around whether allowing certain types of fishing in an MPA may have negative effects on ecosystem structure and biodiversity. In contrast to partially protected areas, they have been shown to deliver significant ecological direct and indirect benefits for fisheries and biodiversity, in tropical and temperate areas.

b) ***Simplicity and cost-effectiveness from a management perspective*** – There is no doubt for users over what activities are allowed within an MPA, making enforcement easier and compliance higher, thereby increasing the economic and ecological return on the high price of MPA designation.

c) ***No preference for certain stakeholder groups*** – Allowing only selected stakeholder groups to carry out extractive activities (e.g. recreational line fishing) in a given area can create conflict. Establishing no-take zones for everyone can be less controversial than identifying selective use zones.

d) ***Provide insurance against changes in future use*** – No-take zones remove the risk of permitted activities increasing in intensity in the future following an MPA establishment, either due to subsequent changes in user behaviour [26] or general population increases.

2) **Strengthening the New Zealand MPA policy guidelines and process so that the levels of protection are sufficient to protect biodiversity**
The amount of no-take zones incorporated into the network can be determined in several ways, either through setting science-based targets for levels of protection (e.g. GBRMP), establishing specific ecological (size, spacing and replicate) guidelines for no-take zones (e.g. GBRMP) or through setting high protection-based thresholds for meeting ecological objectives (e.g. MLPA Initiative).

Since the MLPA Initiative delivered MPA-specific levels of protection amounting to a significant proportion of NTZs in the overall network, we would recommend this approach as an exemplary outcome that successfully balances cutting edge ecological objectives and stakeholder participation. However, the MLPA Initiative was dependent upon a number of factors being successfully implemented together (e.g. strong policy, solid SAT mandate, clear science-based guidelines, close SAT-stakeholder working relationship and powerful decision support tools). Where these conditions are present, we would strongly recommend an MLPAstyle approach, but where this enabling environment may not be possible, we would recommend the approach of using simple science-based and habitat specific targets, as well as associated size, spacing and connectivity guidelines, as this would seem to offer the lowest risk with greatest potential ecological success.

Whatever the final approach to establishing NTZs (NTZ target or combination of other guidelines), the associated guidelines should be explicit and criteria-driven so that stakeholder progress can be evaluated and any proposals can be justifiably assessed according to the necessary goals. Should the target approach be adopted, great care should be taken in establishing the necessary targets to ensure that these are precautionary, applicable to the regional habitats and developed with stakeholders to ensure long-term support.

3) Ensure that establishing levels of protection for MPAs is an integral part of the stakeholder design process

This aspect is so important to the success of the process that it must be very closely associated with any consideration of spatial areas. Stakeholders are unlikely to recommend MPAs unless restrictions can be established, and NTZs are usually highly controversial. The simplest approach follows that of the GBRMP, which established defined zones with clearly, articulated activity restrictions associated with them. Recommendations were made to fit to these zones and overall network design had to meet the necessary target criteria for NTZ coverage. Although it is efficient, this process risks overlooking the specific needs of a site in order to fulfill fairly generic targets. Since activity restrictions will depend upon the habitats in question and the activities occurring, they should ideally be site-based for maximum conservation value. As the UK MCZ Project demonstrated, overly prescriptive methodologies for achieving appropriate site-based protection could cause considerable problems that undermine the outcomes. However, the MLPA Initiative managed to achieve site-specific protection levels in the stakeholder planning process by developing a simple conceptual model that allowed, via live decision support software tools and instant evaluation by the necessary decision makers. As noted above, however, this successful method does require the presence of several enabling factors, which should not be overlooked.

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Chapter 3: The fisheries benefits of Marine Protected Areas

Over the last few decades, the need to protect our threatened ocean biodiversity and rapidly declining fish stocks has become an urgent priority for both conservationists and fisheries managers. Marine Protected Areas (MPAs), being permanent, have historically been used as a conservation tool to protect threatened habitats, whereas fisheries management areas tend to be temporary closures. However, MPAs are increasingly being encouraged as an ecosystem-based approach to managing our natural resources, including fisheries. The potential dual role of MPAs tends to spark some debate regarding the potential to deliver 'win-win' scenarios for conservation and fisheries [1].

This chapter looks for demonstrated examples of MPA benefits to fisheries that would strengthen support for a more coherent, collaborative approach to conservation and fisheries management. Unfortunately, the task of demonstrating the effects of MPAs on fisheries is not an easy one, since it can take considerable time for these sites to reveal their impact and the value of any improvements are often hard to quantify [2]. Very few large MPA networks have been in place long enough to support any noticeable biological or socio-economic change in adjacent fisheries, so supportive evidence is usually derived from theoretical modelling, rather than long-term experimental case studies, which are especially rare in temperate regions [3,4].

However, as the number of established MPAs grows, so too does the empirical data available to assess the effects of such management tools. In addition to their contributions to conservation science, MPAs do provide us with case studies for resource economics and management [2], but the difficulties associated with achieving ideal experimental design make extracting the socio-economic findings potentially even more difficult than proving the biological ones [5].

In order to provide benefits to fisheries, MPAs need to successfully protect and enhance the populations of commercially valuable species, such that they improve overall yield, catch per unit effort (CPUE), or profit of an adjacent fishery. However, these socio-economic effects are the final link in a complex chain. Biological conditions must allow fish populations to increase inside MPAs, sustaining their own larval recruitment, to a point where they "spillover" into open areas to be caught or export their larvae to other areas [6] and the potential for spillover and larval export will differ for each species depending on their mobility, reproductive biology, longevity and other life-history traits [7].

Unequivocal empirical evidence for improved fishing conditions as a direct result of MPA establishment (rather than as a result of other factors, such as reduced fishing effort outside) is therefore tough to find. Ideally, this would require: 'before' and 'after' controls for replicate MPAs in any given location to prove the direct reserve effects on stocks within the boundaries; removal of all potentially confounding factors around the reserves (e.g. changes in fishing effort, distribution, gear type); a clear density gradient of fish stocks declining with distance from the reserve; and improved yield for fisheries that is independent of effort, vessel power and technology, as well as climatic and environmental variation.

Since perfect experimental conditions are so rare in reality, theoretical models have often been used to explore the likelihood of spillover, dispersal or improved fisheries. Empirical case studies have often simplified the situation by focusing on the direct and indirect benefits of MPAs separately, looking only at biological improvements within reserves or observing the result of MPA designation on fishers' behaviour, perceptions or yield data and making well-informed suggestions as to the cause. Given the added layer of complexity incurred by any economic analyses of these results, far fewer studies and published papers have examined the socio-economic benefits of MPAs to fisheries [8] , and these studies tend to rely on qualitative rather than quantitative results.

Increase in biological characteristics

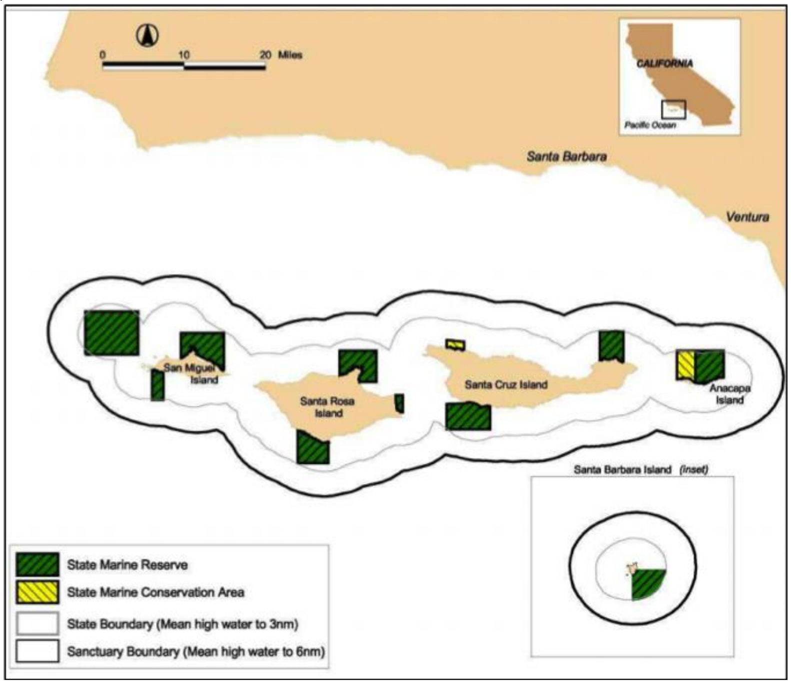
With regard to the direct effects of MPA performance, several reviews of the literature have tackled the issue of improved biological effects within reserves [e.g. 7,9,10]. Despite early claims that results of many scientific studies were ambiguous [6], major global analyses of numerous marine reserves throughout the world are consistent in showing that on average, the majority can be seen to have a positive effect on previously harvested species, with some impressive increases in biomass, density, size and species richness within their boundaries [7,9], often within short timescales [11].

Although there has been suggestion that temperate ecosystems do not show a similar pattern due to the increased mobility and longer larval dispersal times of species, temperate reserves showed the same effects, and in some cases (e.g. for density and biomass) displayed even more pronounced effects than within tropical reserves [7], as demonstrated by the increases in target fish species within the California Channel Islands reserves [3,12].

Where previously MPAs were considered likely to provide such benefits only for smaller, sedentary or site-faithful species [13], some larger reserve networks like the Great Barrier Reef Marine Park are seeing benefits to larger, more mobile species, such as dugongs, turtles and sharks [14]. In addition, increasing evidence is emerging for the same sorts of direct benefits to occur in large-scale and offshore MPAs [15,16]. Thus the role of reserves in protecting harvested species within their boundaries is unequivocal, assuming they are designed properly and adequately enforced.

BOX 1. California Channel Islands

The Channel Islands National Marine Sanctuary (CINMS) off the coast of Santa Barbara supports several important fisheries, and is one of the ten most economically important spiny lobster (*Panulirus interruptus*) fisheries in California waters [17]. In 1999, fishermen campaigned to the California Fish and Game Commission to create a network of marine reserves in the CINMS [18]. In 1999, a systematic and participatory designation process began, following a clear set of science guidelines and in 2003, 10 marine reserves (no-take zones) and 2 partially protected MPAs covering a total of 12% of California State waters were established in law. These reserves then contributed to the MLPA Initiative that immediately followed.



In their examination of 16 reefs inside and outside of three of the CINMS reserves, Kay and Wilson [19] found that the mean total mortality of female lobsters was significantly lower at sites inside reserves than outside and that there was a positive relationship between mortality and proximity to reserve borders, a relationship that was not observed outside of reserves.

In contrast to single MPAs, networks of MPAs are designed to capture the variation in habitats and, like the CINMS network, are often situated across environmental gradients, making it difficult to evaluate the strength of any biological response observed. Five years after the designation of the network, Hamilton et al. [12] analysed the densities and biomass of fish species and controlled for the biogeographic gradient across the reserves. Although they found no significant difference in biological effects for non-commercial species, targeted species densities were on average 1.45 times greater inside reserves than outside. An even stronger trend was found for biomass of targeted species inside and out (average of 1.8 times greater biomass), with no marked difference for non-targeted species.

Evidence for spill-over and larval dispersal

The potential benefits from reserves for fisheries arise either through the recovery and subsequent spillover of adults and juveniles into adjacent fisheries, or the extensive dispersal of larvae that results in successful recruitment elsewhere [20].

Several studies have concluded that the biological effects of MPAs generally provide some considerable benefits to fisheries by replenishing and sometimes improving them through the 'spill-over' of adult target species [21–23]. A clear example of this is found in two small marine reserves established for coral reef fishery protection at Apo Island and Sumilon Island in the Philippines. A study by Russ and Alcala [24] showed that increasing fish density and species richness that was strongly correlated with reserve age but research in the open fished areas around the reserve also showed such increases over time, most pronounced closest to the boundaries, strongly suggesting a density-dependent spillover effect had occurred [21].

It has been well demonstrated that due to the accumulation of large individuals in reserves, the reproductive output of harvested species can be considerably greater from reserves than adjacent areas [25]. However, the importance of larval production from reserves to adjacent fished populations has until recently been largely unknown and very hard to quantify. In a study in the Great Barrier Reef Marine Park, Harrison *et al.* [26]used genetic techniques to estimate the actual contribution of larvae produced in marine reserves to the greater larval pool. They estimated that no-take reserves, which accounted for just 28% of the local reef area, produced approximately half of all juvenile recruitment of coral trout to both reserve and fished reefs within 30 km. Consequently, populations in reserves can provide a significant source of larvae to maintain and replenishment populations outside reserves. While it is more difficult to demonstrate and quantify than adult spillover from reserves, the role of reserves as a potential source of larvae for fished populations is of greater consequence to fisheries management than movement of adults beyond reserve boundaries.

BOX 3: Leigh Marine Reserve, New Zealand

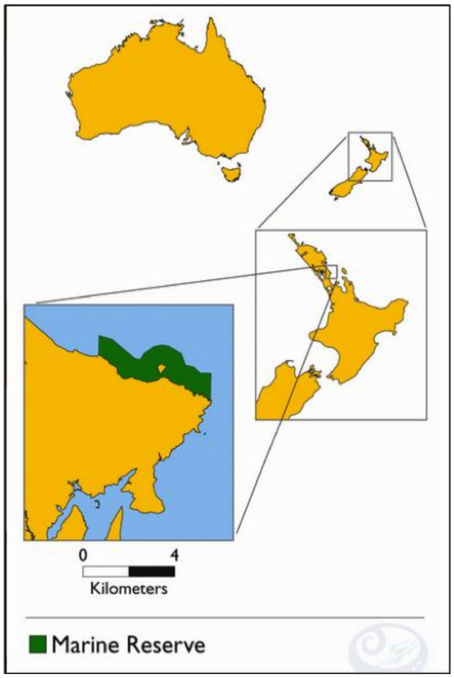


Figure 7. Leigh Marine Reserve, NZ

The Cape Rodney to Okakari Point (Leigh) Marine Reserve is New Zealand's oldest marine reserve and is also the most well studied. Following protection in 1975, the abundance and size of snapper (*Pagrus auratus*) and spiny lobster (*Jasus edwardsii*) increased substantially within the marine reserve [11]. Over the subsequent years this increase in predatory species had cascading effects on lower trophic levels with declines in sea urchins and consequent indirect increases in kelp [27]. The ecological changes within the reserve are clear and the evidence for them being related to protection from fishing are strong given the availability of baseline data from before reserve establishment as well as through comparison with non-reserve sites and experimental studies. How these changes within the reserve benefit adjacent fisheries are less well understood and the evidence for positive effects on adjacent fisheries is circumstantial.

Given the higher biomasses and larger sizes of both snapper and lobster in the reserve compared to adjacent fished areas the egg production of both species is considerably higher [25,28]. For example, Willis *et al.* [25] estimated that a reserve the size of Leigh (c. 5 km of coastline) might conservatively produce a quantity of snapper eggs equivalent to that produced by c. 90 km of unprotected coastline. These studies demonstrate how protection of harvested species even within small reserves can contribute disproportionately to the greater larval pool.

The Leigh Marine Reserve is approximately 5 km long and the alongshore boundary is only 800m offshore. Movement studies on both snapper and lobster indicates that these species frequently move beyond the offshore boundary [29–31] and are consequently vulnerable to fishing. Trapping studies utilising commercial fishermen found that CPUE along the offshore boundary of the reserve was no different to the adjacent unprotected coastal areas [32]. However, due to the limited offshore extent of the boundary (800 m) intense fishing on this boundary is thought to have led to subsequent declines in the abundance of lobsters in the reserve [11,33]. While, Kelly *et al.* [28] indicated that the reserve did not have a negative effect on the livelihood of local fishers, the subsequent declines suggested that the offshore extent of the reserve was not sufficient to protect resident populations of lobster. Similarly, a more recent modelling study on snapper (Babcock et al 2012) that utilised acoustic telemetry data to define different behavioural modes of snapper indicated that marine reserves with sizes similar to Leigh (c. 5 km^2) were too small to fully protect resident reserve snapper populations. While these studies indicate that populations of target species within the Leigh reserve contribute to adjacent fisheries through adult spillover, they also highlight that the reserve size, particularly the distance to the offshore boundary, is not sufficient to fully protect these species.

Socio-economic improvements

So with strong evidence of the role of MPAs in protecting exploited species and increasing evidence to suggest or demonstrate spillover effects from marine reserves, what results have been shown for the associated socio-economic effects of reserves on yield, catchability or revenue?

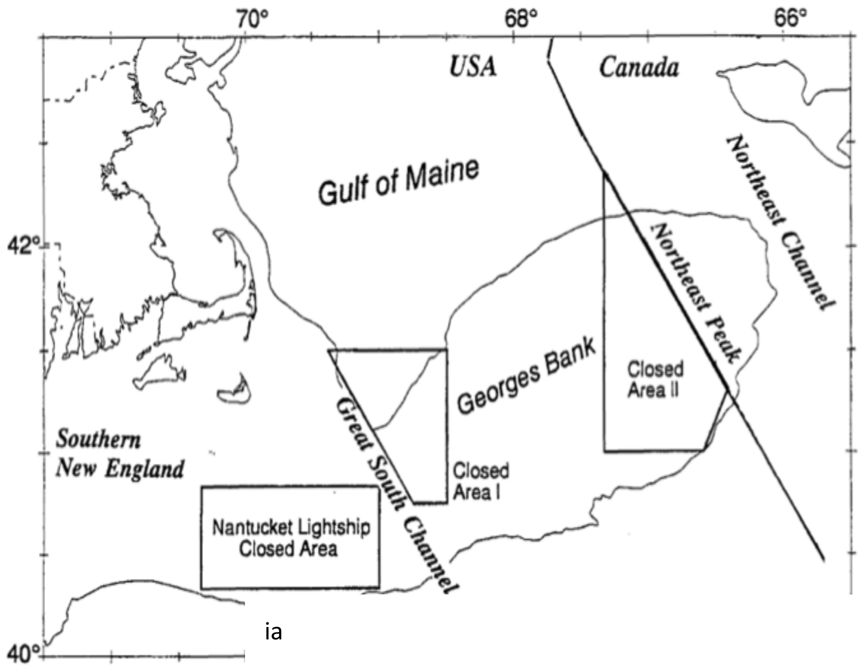
Theoretical models have predicted a range of reserve benefits for fisheries, including equivalent or improved yields compared to fishing a fixed-fraction of the population [34], increased CPUE adjacent to reserves for more mobile species, and no net loss of benefits from fishing displacement, provided the placement of an MPA did not redirect fishing effort to an area where spawning stocks were even more vulnerable [4]. Gaines *et al.* [35] synthesized the results from 57 papers explicitly modelling the effects of reserve networks on expected fisheries yield or profit and found that more than half reported reserves to benefit fisheries and, of those, most found that optimum benefits occurred through the protection of almost 50% of fisheries area.

While these results suggest potential benefits theoretical models are necessarily simplistic views of a very dynamic ecosystem, and tend to overlook important aspects of reality, such as species mobility, habitat heterogeneity, and variations in fishing patterns [4], as well as fishing displacement or irreversible ecosystem changes caused by overfishing [6].

When turning to real-world examples, observable patterns in fishing behaviour around MPAs can suggest a perceived benefit to local fisheries. Direct observations and satellite tracking have exposed 'along the line' fishing behaviour, where vessel movement patterns cluster around the reserves and tightly trace their boundaries where one would expect the greatest MPA spillover effects [13,22,36,37]. Reviewing the empirical data to support fisheries benefits from scientifically robust MPA designs, Gell and Roberts [5] highlighted studies in Kenya [23], Egypt [38], St Lucia [39] and South Africa [40] that indicated CPUE for commercial fish species was significantly higher either within MPAs, or nearer to the MPA boundaries. The two previously mentioned marine reserves at Apo and Sumilon Islands in the Philippines were repeatedly closed and reopened to fisheries over two decades, with corresponding increases and decreases in fisheries catch [22]. In this instance, fishers benefited from CPUE rates that were 45 times higher within 200m of the Apo Island reserve, compared to all other fishing grounds [41].

BOX 2: Georges Bank, Gulf of Maine, USA

Georges Bank is a shallow bank and legendarily productive fishing ground [37] for groundfish species such as cod, haddock and yellowtail flounder. Due to declining groundfish stocks and fear of fisheries collapse, three areas across Georges Bank (Area I, Area II and the Nantucket Lightship Closed Area; see Fig 8) totaling 17,000km^2 were permanently closed to all ground trawling fishing gears from 1994 [13].



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These marine reserves were clearly established as spatial fisheries management tools to diversify existing management efforts and mitigate the stock declines that were not responding to more traditional measures. Closed areas were selected based upon the presence of vulnerable groundfish nursery areas.

Protection levels inside these closed areas were dictated by the proportion of stock protected within the closures (17-29% of the species range across all three areas), the movement of vulnerable sizes into open areas (limited movement for groundfish species), and the level of fishing effort outside. Simultaneously, this surrounding fishing effort was significantly controlled, with measures including a 50% reduction in mobile fleet fishing effort, an increase in minimum mesh size, a moratorium on new vessels in the area and trip limits for haddock and cod [13].

By 2001, stocks of target groundfish species had rebounded dramatically; haddock populations increased five-fold, yellowtail flounder increased 8-fold and biomass increases of 50% were seen for cod. Scallop biomass had increased 14-fold [37] and densities of legal sized scallops were 9-14 times greater than fished areas outside the closed areas [cited in: 5]. Additional benefits were also noticed, such as the recovery of benthic habitats after the removal of bottom trawling gear pressure.

Indirect indication of spillover of fish into open areas was demonstrated in spatial analysis of satellite-tracked vessel information, showing significant fishing effort had been redirected around the boundaries of the closed areas [36], also known as "fishing-the-line". Areas showing the highest fishing concentration were the same as those that would be predicted to have the highest scallop larvae export from the closed areas [cited in: 5].

Drawing conclusions for fisheries benefits

These examples of empirical evidence demonstrate that MPAs can provide benefits to fisheries from increased catch rates. However, the evidence base is still small and given the substantial differences between conditions, it may therefore be unwise to suggest these results can be generalized elsewhere [42,43]. In certain case studies, such as Georges Bank and Apo Island, it is noteworthy that the objectives of the reserves were entirely focused upon stock protection and sustainability and that wider biodiversity or conservation benefits were not main priorities. Both scientists and fisheries managers concede the difficulty in establishing direct cause and effect between closed areas and fisheries benefits, particularly when it is accepted that for some target species, complementary fisheries management measures outside reserves can be as important in reducing fish mortality as the reserves themselves [7,13]. In the case of Georges Bank, we can only conclude that it was the combination of closed area marine reserves and reduced fishing efforts that succeeded in meeting specific fisheries recovery objectives. Similarly, fisheries managers in Apo Island supported the reserve approach as one of the only viable options for recovering a tropical coral reef fishery, given the limited mobility of adults and the complications associated with implementing more conventional fisheries measures in coral reef habitats [24].

This raises the key issue of establishing specific objectives for reserves, against which empirical results can be judged and success evaluated. Several authors have expressed concern that overzealous advocacy for MPAs has lead to lack of rigorous scientific testing against such explicit objectives, which may damage the credibility of MPAs as a valid tool for fisheries management when designed appropriately [42,43].

Marine reserves alone cannot overcome issues such as intense or unregulated fishing pressure outside their boundaries [44] or lack of compliance within their boundaries [45], both of which can exert a strong influence on whether fisheries recover [43]. Without specific objectives for fisheries management, marine reserves may not benefit from the complementary fisheries regulations and enforcement (voluntary or otherwise) that appear to have been integral to the success of Georges Bank and Apo Island.

The successful recovery of a fishery through spatial measures such as a reserve will depend on prior knowledge of and specific design for all the necessary life-history characteristics of the target species [35,43]. While growing numbers of success stories have led to emphatic arguments that MPAs have delivered both conservation and fisheries benefits, their undoubted success may be more circumstantial than by specific design. The development of MPA networks is still largely in its infancy worldwide and scientific research is only just starting to provide answers to some of the big questions regarding the fishery benefits of MPA networks. The signs from GBRMP are very promising [26] and over time the potential benefits of this MPA network, and others, to fisheries will be borne out by further study.

With continual improvements in our knowledge and useful lessons learned, the suggestion is that designing reserves specifically for both fisheries and conservation benefits is technically possible and highly desirable, but most current MPAs are too small to deliver the biological conditions necessary to promote fishery recoveries and the vast majority are still single, isolated reserves, struggling in a sea of increasing pressures without the multiplicative benefits provided by large networks of no-take and multiple use MPAs [35]. Analysis of existing reserve performance has led to clearer science guidelines in future network design to achieve improved fisheries benefits without the implicit trade-off against conservation goals [35]. Any potential 'win-win' scenario must therefore be accompanied by a far greater collaboration between fisheries and conservation to achieve successful ecosystem management [1].

Although large MPA networks are now being designed or implemented to hopefully fulfill this dual expectation (e.g. California MLPA, GBRMP), the debate is by no means concluded. Overfishing is only one of the numerous negative pressures facing ecosystem persistence, and in marine environments, pollution, climate change and cumulative impacts present increasingly worrying threats. However, it is important to recognise that unlike these other impacts, the impacts of fishing can be easily controlled and effectively eliminated spatially with the use of MPAs. Although MPAs should not be expected to achieve long-term conservation success on their own [35,46], large, well-designed MPA networks offer insurance policies against current and future risks to both fisheries and biodiversity [47].

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Appendix 1: Comparison of all four case study MPA network design processes

	AUSTRALIA	CALIFORNIA	UK	NEW ZEALAND
Name	Great Barrier Reef Marine Park Representative Areas Program (RAP)	California Marine Life Protection Act Initiative (MLPA Initiative)	United Kingdom Marine Conservation Zones Project (UK MCZ Project)	New Zealand MPA Policy
Dates	Original GBRMP zoning established in 1975; RAP dates 2002 - 2004	2000 and 2002 (unsuccessful); 2004 – 2012 (successful process and final designation of all four regions)	2009 – present	Started in 2005 and is currently underway
Status	Complete: zones designated in 2004.	Complete; zones designated	Recommendations (Sept 2011) followed by public consultation (Jan-Mar 2013). First set of 31 MPAs (none are highly protected) have been put forward for potential designation in 2014.	Final decision pending for both regions following public consultation
Outcome	An improved Zoning Plan with no-take zones increased from 3% to 33.5%	A total of 124 MPAs designated (including 12 California Channel Islands MPAs), covering 16.0% of total state waters (2197 km^2), 61 of which were no-take zones covering 9.4% of state waters (1281 km^2)	As yet unknown. 127 MCZs (and 65 highly protected areas) were recommended by stakeholder groups (in 2011), but at the time of writing, the Government has selected only a first tranche of 31 MCZs for potential designation, with no highly protected areas.	**South Island West Coast** - 4 NTZs (protecting 1.3% of the Territorial Sea) and 2 MPAs (0.7% of the Territorial Sea) recommended. **Sub-Antarctic Islands** - 3 NTZs were recommended, covering 39% of the Territorial Sea around Campbell Island, 58 % of the Territorial Sea around the Bounty Islands and all of the Territorial Sea around the Antipodes Islands.
Legislation	GBRMP Act (1975)	Marine Life Protection Act 1999	Marine and Coastal Access Act 2009	Marine Reserves Act 1971 (under review) Fisheries Act 1996
Policy	Australia's Ocean Policy	MLPA Master Plan	Guidance Note 1 Ecological Network Guidance	Marine Protected Areas Policy and Implementation Plan 2005 (MPAPIP) Marine Protected Areas: Classification, Protection Standard and implementation Guidelines 2008 (MPACPIG)
Extent	Between 60 and 250 km wide, the Park covers a total area of 344,400km^2 from the northern tip of Queensland, NE Australia, to just north of Bundaberg, close to the easternmost point of Australia.	Mean High Water to 3nm offshore along total length of the California coastline	English waters from Mean High Water to 200nm (or neighbouring EEZ)	Entire marine environment including estuaries, the Territorial Sea (within 12 nautical miles of the coast and islands), and the Exclusive Economic Zone (12 to 200 nautical miles)

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	AUSTRALIA	CALIFORNIA	UK	NEW ZEALAND
Ecosystems	The world's largest coral reef ecosystem, protecting some 3000 coral reefs, 600 continental islands, 300 coral cays and about 150 inshore mangrove islands.	Temperate rocky reefs, intertidal zones, sandy or soft ocean bottoms, underwater pinnacles, kelp forests, submarine canyons, and seagrass beds.	23 Broad scale habitats were identified from the European classification system (EUNIS), describing biogenic reefs and intertidal, infralittoral, circalittoral and subtidal rock and mixed sediment habitats characterized by high, medium and low energy levels.	Hierarchical coastal classification system: Biogeographic region (13)/Environment type (Estuarine/Marine)/Depth (Intertidal, 0-30 m, 30-200 m)/Exposure(low, med, high)/Physical habitat type (Mud, Sand, Rock etc)
Governing agency	Great Barrier Reef Marine Park Authority	California Fish and Game Commission; California Department of Fish and Game; California Resources Agency	Natural England (NE) and Joint Nature Conservation Committee (JNCC)	Department of Conservation; Department of Primary Industries (formerly Ministry of Fisheries)
Fisheries objectives	Not the priority of the rezoning process, but the GBRMP had strong provision for fisheries within its existing zoning plan and this was maintained.	Selected commercial fish species and populations were included for protection	None (the UK has a fisheries quota system established under the European Common Fisheries Policy)	Not incorporated into MPA process
Goals	• Maintain biological diversity at ecosystem, habitat, species, population and gene level • Allow species to evolve and function undisturbed; • Provide an ecological safety margin against human-induced impacts; • Provide a solid ecological base from which threatened species or habitats can recover or repair themselves; • Maintain ecological processes and systems	• Protect marine biodiversity • Protect and restore marine life populations • Improve recreational, educational and study opportunities in MPAs while maintaining their objectives of protecting biodiversity • Protect marine life heritage for the inherent value of habitats • Ensure MPAs have clear objectives, effective management measures, adequate enforcement and are based on sound scientific guidelines • MPAs are designed and managed as a network	MCZs may be designated to conserve and/or aid the recovery of: • The range of marine biodiversity in our waters; • Rare or threatened habitats and species; • Globally/regionally significant areas for geographically restricted habitats or species; • Important aggregations or communities of marine species; • Areas important for key life cycle stages of mobile species, including habitats known to be important for their reproduction and nursery stages; • Areas contributing to maintenance of marine biodiversity and ecosystem function; • Features of particular geological or geomorphological interest	The MPA Policy objective is to: Protect marine biodiversity by establishing a network of MPAs that is comprehensive and representative of New Zealand's marine habitats and ecosystems [as required under the NZ Biodiversity Strategy (NZBS) 2000, ratification of the international Convention on Biodiversity]
Guidelines	11 Biophysical Operating Principles and 4 Socio-economic Principles were recommended by the Scientific Steering Committee and other experts	9 scientific 'guidelines' covering ecological and human aspects of design. 2 socio-economic guidelines to take account of local resource use/stakeholder activity and	7 Design Principles describe 19 ecological guidelines, with 11 additional 'further consideration' guidelines. An overarching objective was to minimise the socio-	Network Design Principles and Planning Principles (MPAPIP). Design guidelines used to identify and select potential protected areas

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	AUSTRALIA	CALIFORNIA	UK	NEW ZEALAND
		adjacent human environment	economic impacts on stakeholder activity	(MPACPIG)
Governance structure	• GBRMP Authority • Scientific Steering Committee • Social, Economic and Cultural Steering Committee • Public consultation via submissions	• Blue Ribbon Task Force – managed and guided the planning process • Science Advisory Team – developed science guidelines • Project Teams – managed the regional planning process with stakeholders • Regional Stakeholder Group – developed recommendations • Statewide Interests Group – improved public involvement in the process	• MCZ Project Team – managed and guided the process • Statutory Nature Conservation Agencies (JNCC/NE) – delivered the science guidelines and project delivery guidance • Science Advisory Panel – assessed the recommendations • Regional Stakeholder Groups – developed recommendations • Regional MCZ Project Teams – managed the planning process	• Department of Conservation and Department of Primary Industries • Regional Marine Protection Planning Forums
Process stages	7) Describe the biological diversity 8) Review of existing protection 9) Develop Biophysical Operating Principles 10) Formal community participation process 11) MPA submissions received a. Draft zoning plan produced and opened to public consultation b. Preparation of revised zoning plan c. Ministerial review and approval 12) Zoning plan adopted	7) Project preparation a) Develop guidelines b) Identify stakeholders 8) Develop ecological/social profile of the region 9) Convene regional stakeholder group planning process (in three iterations) a) Establish MPA sites to meet guidance b) Assemble draft regional MPA networks c) Evaluate draft regional MPA networks 10) Review of proposals 11) Public consultation 12) Designation	9) Project preparation a. Identify stakeholders b. Develop guidelines 10) Stakeholder group formation and data collation 11) Develop ecological/social profile of the region 12) Convene regional stakeholder group planning process ((in three iterative stages) a. Establish MCZ sites b. Evaluation of progress c. Finalise recommendations 13) Develop Impact Assessment 14) Review of recommendations and formal submission to Government 15) Public consultation 16) Designation	1-2. Develop classification approach and Refine the protection standard 3-6. Map existing management tools, develop MPA inventory, identify gaps prioritise new MPAs. 7-9. Nearshore implementation (regional approach), Offshore implementation and Designation of new MPAs 10. Monitor and evaluate MPA network
Types of MPAs	• Preservation zones • Marine National Park Zones • Scientific Research Zones • Buffer Zones • Conservation Park Zones • Habitat Protection Zones • General Use Zones • Commonwealth Island Zones	• SMCA – State Marine Conservation Area • SMP – State Marine Park • SMR – State Marine Reserve	MCZs are one type of MPA but can have any combination of restrictions depending upon the features for conservation and the impacts upon them. 'Reference Area MCZs' are highly protected areas with no extraction, deposition or disturbance	Two types of MPAs: Type 1 MPAs (marine reserves) and Type 2 MPAs (other management tools that meet the protection standard)

Appendix 1: Comparison of all four case study MPA network design processes

	AUSTRALIA	CALIFORNIA	UK	NEW ZEALAND
No-take zone target within the network	"No-Take Areas" 20% of each habitat to be contained within NTAs except smaller areas. (33% achieved.) No-take areas (NTAs) should be at least 20 km long on the smallest dimension (except for coastal bioregions)	None specified (determined by default through application of other design principles)	"Reference Areas": 1 example of each feature to be included within a viable 'Reference Area' with no damaging, depositional or disturbing activities permitted.	None specified. The NZBS aimed to achieve a target of protecting 10% of New Zealand's marine environment by 2010 in view of establishing a network of representative protected marine areas but does not specify no-take
Habitat represen-tativity	1) Include typical examples of each community and physical environment type (BOP 7) 2) Include biophysically special/unique places (BOP 9) 3) Represent cross-shelf and latitudinal diversity in the network of no-take zones (BOP 11)	4) All key habitats should be protected (N.B. these were listed, with depth zones and important oceanographic habitats, but the list was often influenced by the regional composition of the SAT) 5) The network should include offshore open ocean to capture those areas that are critical for lifecycle stages 6) Habitats with unique features or those that are rare, should be targeted for inclusion	1) Include examples of all 23 EUNIS Level 3 broad-scale habitats in the network 2) Include examples of all listed rare and threatened habitats specified 3) Include examples of all listed rare and threatened species of low and high mobility	1) Protect the full range of marine habitats and ecosystems 2) MPAs should be designated based on a consistent approach to classification of habitats and ecosystems 3) Represent latitudinal and longitudinal variation
Adequacy (habitat coverage)	1) Represent at least 3 reefs and 20% of reef area and 20% of reef perimeter in each reef bioregion in no-take areas (NTAs) 2) Represent a minimum amount (20%) of each non-reef bioregion in NTAs, with specific habitats requiring special provisions	None specified (Incorporated in design through guidelines on minimum size and maximum spacing of MPAs)	Specific percentage targets (minimum and maximum thresholds) given for each broad-scale habitat and feature of conservation importance	None specified
Viability (size)	1) No-take areas (NTAs) should be at least 20 km long on the smallest dimension (except for coastal bioregions) 2) For a given amount of area to be protected, protect fewer, larger areas rather than smaller areas, particularly to minimise 'edge effects' resulting from	1) 5-10km min (10-20km preferred) length 2) Must extend from intertidal to deeper offshore	1) MCZs for broad-scale habitats should have a minimum diameter of 5 km with the average size being between 10 and 20 km in diameter 2) Patches of habitats of conservation importance within MCZs should have a minimum diameter as specified (minimum	1) Protected areas may be of various shapes and sizes but should be of sufficient size to provide for the maintenance of populations of plants and animals. 2) Have fewer larger (versus numerous smaller) protected areas

Appendix 1: Comparison of all four case study MPA network design processes

	AUSTRALIA	CALIFORNIA	UK	NEW ZEALAND
	use of the surrounding areas. 3) Where a reef is incorporated into NTAs, the whole reef should be included to avoid fragmentation		patch size = 0.1km).	[Secondary consideration]
Replication	1) Represent at least 3 reefs and 20% of reef area and 20% of reef perimeter in each reef bioregion in no-take areas 2) For most bioregions, 3–4 NTAs are recommended. For some very small bioregions fewer areas are recommended, whilst for some very large or long bioregions, more no-take areas are recommended.	3-5 examples of each habitat per biogeographic region	In each biogeographic region: 1) 2 examples of each EUNIS Level 3 broad-scale habitat 2) 3-5 examples of each key feature	Consideration should be given to whether the site provides replication of habitats and ecosystems in a biogeographic region. [Secondary consideration]
Connect-ivity	1) Avoid fragmentation - Where a reef is incorporated into a site, the whole reef should be included	1) Sites should be separated by 50-100km	1) Known species-specific dispersal distances or critical areas for life-cycles of listed species should be used to determine the spacing between MPAs 2) MPAs of similar habitats should be separated, where possible, by no more than 40 – 80 km 3) Connectivity may be approximated by ensuring that MPAs are well distributed across the regional MCZ project areas	1) Maximise connectivity – the design of the protected area network should seek to maximise and enhance the linkages among individual protected areas, groups of protected areas within a given biogeographic region, and across biogeographic regions.
Scientific evidence and develop-ment of guidelines	1) Use all available data ***(BOP 9)*** 2) Include consideration of sea and adjacent land uses in determining NTAs (***BOP 11***)	Best available data	Best available data	Planning Principle 7: Best available information will be taken into account in decision-making.