Biological Conservation xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Perspective

Long live Marine Reserves: A review of experiences and benefits

Mark J. Costello *

Institute of Marine Science, Leigh Marine Laboratory, University of Auckland, New Zealand

ARTICLE INFO

Article history:
Received 8 February 2014
Received in revised form 13 April 2014
Accepted 23 April 2014
Available online xxxx

Keywords:
Marine Protected Areas
Ecosystem based management
Species conservation
Socio-economics
Climate change
Fisheries
Ecology
Experimental controls

ABSTRACT

This paper reviews the socio-economic, ecological, and conservation experiences during the establishment of Marine Reserves (no-take Marine Protected Areas (MPA)) in New Zealand in an international context. Once operational, reserves became popular with the public and provided economic benefits. In one reserve, 'spill-over' of lobsters counter-balanced lost fishing. The reserves provided the control sites that showed the effects of fishing on ecosystems through depleted populations and habitat change due to trophic cascades. Studies in other countries indicated that these trophic cascades were common globally. Research showed reserves protect benthic and pelagic species, including those that move outside the reserves. These findings benefited from reserves having a map of seabed habitats and data on the relative abundance of species of ecological importance. Information on other species (e.g. macro-invertebrates), and previous and nearby fishing effort over time, may have provided additional insights.

Marine Reserves can provide benefits to (1) conservation of species and habitats, (2) science as controls for fishing effects, and (3) fisheries as reference sites that conserve natural genetic and population structure, host brood-stock, and provide spill-over to nearby fisheries. They should be distributed geographically in networks that include replicated examples of habitats and species. To do so, they need to be suitably located, large enough, and enforced to fulfil these opportunities. However, these benefits remain limited by the relatively small area occupied by Marine Reserves within and between countries.

Contents

1. Introduction

There were many unexpected social, economic, educational and ecological changes following the creation of the first marine reserve in New Zealand. Its establishment was the basis for the first paper on Marine Reserves in this journal (Ballantine and Gordon, 1979), and the experience since then is reviewed in this issue of *Biological Conservation* (Ballantine, 2014). The reserve has variously been called Goat Island, Leigh, and officially the Cape Rodney to Okakari Point (CROP) Marine Reserve. It extends 800 m from the shore along 5 km of coast. A new law, the Marine Reserve Act 1971 was passed to establish this reserve and paved the way for 36 more. Here, Marine Reserves are no-take Marine Protected Areas (MPA) following legal usage in New Zealand and some other countries. There were just 10 papers on marine reserves in this journal until 1995, but 12 from 1996 to 2000, 20 from 2001–2005, 49 from 2006–2011, and over 53 since 2010, reflecting the increased scientific attention to marine conservation. This paper summarises the findings from New Zealand in the context of the history of Marine Reserve related papers in this journal.

* Tel.: +64 93737599.
E-mail address: m.costello@auckland.ac.nz

http://dx.doi.org/10.1016/j.biocon.2014.04.023
0006-3207/

1.1. Socio-economic responses

Initially CROP Marine Reserve was proposed to keep the area free of interference so that scientists could do their research and experiments, and distinguish natural environmental change from that due to human activities. The reserve now attracts thousands of school children, and tens of thousands of members of the public every year (Walls, 1998); Hunt (2008) estimated 375,000 visitors from March 2007 to February 2008 inclusive. This ecotourism has been valued at over NZ$8 million a year, but with a conservation management budget of only NZ$70,000 (Hunt, 2008). However, the visitor's emotional experiences may be as or more influential than these financial benefits. People now appreciate what marine life would be like around the coast if it is not fished. The New Zealand experience is that some of those who may have objected to a Marine Reserve at first, supported it once established because they could see the socio-economic benefits to the community and are not significantly deprived (Cocklin et al., 1998; Walls, 1998; Taylor and Buckenham, 2003). Nevertheless, there are usually some objections whenever a new reserve is proposed.

Economic studies that consider the wider social and economic benefits of reserves find that in some circumstances they could exceed the lost profits from fishing (The Allen Consulting Group, 2009; Yamazaki et al., 2012), can make fishing more profitable (similar catch for less effort) (Claudet and Guidetti, 2010), and fisheries displacement did not compromise the socio-economic well-being of fishermen in Hawaii (Stevenson et al., 2013). The experience at CROP Marine Reserve supports this. The presence of the reserve did not reduce regional catches of spiny lobster (crayfish) because there was a 'spillover' of lobsters out of the reserve (Kelly et al., 2002). Larger lobsters were captured near the reserve (Kelly et al., 2002). Socio-economic benefits have also been found in other countries, for example in Palau shark-watching has been found to be 100-times more valuable than the value of their meat (Vianna et al., 2012). Indeed, through spillover, reserves may be considered a long-term beneficial subsidy to fisheries (Cullis-Suzuki and Pauly, 2010).

It was fortunate that the first Marine Reserve in New Zealand was easily accessible to the public, and within two hours drive of the largest city in New Zealand. This meant people saw the increased abundance of fish and spiny lobsters (crayfish), and more people came to see the marine life (Walls, 1998). The fish lost their fear of people, were easily approached (Towns and Ballantine, 1993; Cole, 1994), and were more residential in the reserve than in fished areas (Parsons et al., 2010). New businesses provided the public opportunities for snorkelling, scuba diving, guided tours, accommodation, shopping, and tours on a glass-bottomed boat (Cocklin et al., 1998; Taylor and Buckenham, 2003). Visitors went home and wondered why they could not have Marine Reserves in their areas. Thus about half of all Marine Reserves in New Zealand were proposed by local community groups including universities, conservation groups, schools and diving clubs. One experience led to the establishment of the 'Experiencing Marine Reserves' programme which trains families to enjoy snorkelling with wildlife within and outside (for comparison) Marine Reserves (Nicholas and Yiu, 2012, http://www.emr.org.nz). Following a long campaign by a local school, a Marine Reserve was established near Whangarei in the north of New Zealand. To celebrate, about 1000 adults and children formed a human chain along its shoreline, with a flotilla of 13 boats along its sea boundary, and a helicopter in the air (Fig. 1). Their "Mexican wave" can be seen on a video posted to YouTube (Hathaway, 2009). Such community support must be a great deterrent against poaching (Taylor and Buckenham, 2003). At the offshore Poor Knights Islands, now also a Marine Reserve, former spear-fishermen look forward to the return of the "herds" of 30–100 large (<1.8 m long, 10–50 kg) hapuku wreck-fish (*Polyprion oxygeneios* (Schneider, 1801)) which occurred in shallow water in the 1960's but were fished out (Doak, 2006; Grace, 2006). Reports of fish sightings indicated their grandchildren may see such impressive herds restored in the reserve.

Fig. 1. The human chain around a Marine Reserve in New Zealand. Photograph by Annelies Struijcken.

The arguments for reserves have been not only about conservation but socio-economic and supported by the science. People wanted natural places to explore in the sea as they had on land. In reserves, the wildlife can be enjoyed by everybody for generations to come. In contrast, increasing human population pressure requires ever more stringent regulations and enforcement to maintain fish size and abundance outside reserves.

1.2. Ecological responses

After over twenty years of research in the CROP Marine Reserve, it was discovered that habitats considered natural were in fact the result of a trophic cascade due to fishing out of large predators (reviewed by Leleu et al., 2012; Babcock, 2013). This experimentally demonstrated that this coastal sea was not a pristine environment, and ecosystems had been altered as well as the abundance of particular fished species. Indeed, it appears that (at least coastal) marine ecosystems throughout the world have been altered by human hunting of mammals, birds, fish, crustaceans, molluscs and other invertebrates for centuries (e.g. Jackson et al., 2001; Lotze et al., 2006; Worm et al., 2006), and increasingly in the deep-sea (e.g. Morato et al., 2006; Davies et al., 2007; Bo et al., 2014). The removal of two million whales from the southern hemisphere in the 20th century was probably preceded by similar reductions in marine mammals in the northern hemisphere oceans where hunting began 300 years earlier (Baker and Clapham, 2004). Four marine mammals were hunted to extinction in the northern hemisphere and about ¼ are threatened with extinction (Pompa et al., 2011). Individual whales range across entire oceans so this hunting may already have changed marine ecosystems at global scales before fisheries went global (Botsford et al., 2004; Springer et al., 2003). If so, we have no sure baselines for marine ecosystems anywhere although some remote locations may be less affected than those close to highly populated regions (Edgar et al., 2014). Marine Reserves, given space and time, are now the best way to understand what 'natural' ecosystems are, even though we may never know their true pristine state.

Many studies recognised the importance of habitats for biodiversity, including their use to guide selection of areas for protection (e.g. Mumby and Harborne, 1999; Edinger and Risk, 2000;

Please cite this article in press as: Costello, M.J. Long live Marine Reserves: A review of experiences and benefits. Biol. Conserv. (2014), http://dx.doi.org/10.1016/j.biocon.2014.04.023

Stevens and Connolly, 2004; Hawkins et al., 2006; Banks and Skilleter, 2007; Stelzenmüller et al., 2007; Howell, 2010; Howell et al., 2011; Tulloch et al., 2013). At CROP Marine Reserve a habitat map had been prepared around the time the Marine Reserve was established, enabling a quantitative spatial comparison of habitat change three decades later (Leleu et al., 2012). This before-after control-impacted (BACI) experimental design showed how, unexpectedly and indirectly, fishing had changed the benthic communities and habitats.

The second Marine Reserve in New Zealand, at the Poor Knights islands, allowed limited fishing. This attracted recreational fishers and rapidly led to a similar loss of fish as in unprotected areas and calls to ban all fishing (Denny et al., 2004). Similarly, marine "parks" which allowed partial take had the same trophic cascade effects as unprotected areas; i.e. in the absence of predators sea urchins grazed the rocks bare, creating so called 'urchin barrens' (Denny and Babcock, 2004; Shears et al., 2006; Taylor et al., 2011). This predator-urchin cascade seems widespread globally (reviewed in Leleu et al., 2012; Coleman et al., 2013), albeit subject to local environmental conditions (Shears et al., 2008). Thus the New Zealand, and international (e.g. Lester and Halpern, 2008; Di Franco et al., 2009), experience was that partially no-take MPA do not protect biodiversity at the species, habitat or ecosystem level. More complex rules also make policing more difficult than in Marine Reserves. Some MPA allow catch and release angling, but whether it is compatible with no-take status is unclear (Cook et al., 2006). Similar findings regarding the so called "Marine Reserve effect", namely increased abundance of species fished and sometimes food web effects, have been found whenever no-take rules have been enforced (Molloy et al., 2008, 2009) (Table 1), and this effect may extend beyond reserves through spillover (Guidetti, 2006a,b). Edgar et al. (2014) conducted a standardised global scuba diving survey of 87 MPa and found each of the factors age, size, isolation and enforcement were significant in protecting fish abundance, biomass and species richness.

The impacts of fishing on fish stocks, prey species, bycatch, and physical damage to habitats are well known, and models can predict effects on ecosystems (e.g. Botsford et al., 2004). However, without Marine Reserves, science would not have had the experimental demonstration (i.e. with controls) of the indirect effects of fishing on communities and habitats through trophic cascades. While scientists' research may be restricted within Marine Reserves because of their conservation status, they also have new opportunities. Marine Reserves are unparalleled 'controls' for understanding how human impacts, primarily fishing, impact biodiversity. For example, using MPA as controls, Edgar et al. (2014) conservatively showed that 63% of all fish, and 93% of shark, biomass has been removed from coastal reefs by fishing.

Fisheries scientists estimate fish stocks based on estimates of population abundance, but many of these populations have already been impacted (1) directly by fishing prior to having standardised data, (2) indirectly by fishing of their predators, prey, and/or bycatch mortality, and (3) possible habitat damage by seabed dredges, trawls or lost fishing gear (Pinnegar and Engelhard, 2008). In Marine Reserves fish populations can recover to more natural levels which allow examination of natural variation in abundance as well as interactions with non-fishery effects (e.g. contamination, sedimentation, warming, acidification) that reserves cannot control for. Thus reserves could provide a unique reference against which fishery managers could judge the direct and indirect effects of fishing some species (Botsford et al., 2004; Edgar et al., 2014). They may help determine maximum age and fecundity, age at maturation, natural mortality, population age and size structure, and set management targets. Indeed, it is surprising that resource management does not use Marine Reserve reference sites as a standard method to distinguish between natural and human causes of fluctuations in resources. In part, this may be because Marine Reserves have not been designed, located, of sufficient size or age, and/or sufficiently replicated to act as particular fish stock reference sites. At least some reserves should be designed as part of regional scale fishery management. Different fishery species would probably require different reserve designs. The design of a network of Marine Reserves, perhaps in conjunction with partial take MPA, may prove a more cost-effective and sustainable way to manage fisheries through providing (a) genetically healthy reference populations, (b) brood-stock habitat, and (c) spill-over.

1.3. Species

Ballantine's (2014) review focused on ecological and social changes rather than particular species of conservation concern. Dulvy (2013) was concerned that the focus on very large MPA, many of which were not preventing fishing and were thus not conserving biodiversity, was distracting from the need to protect species. At least this is not the case for the science which is giving at least as much attention to threatened species. Many studies in this journal and elsewhere consider both, that is, the role of MPA in protecting species, and such large MPA would especially benefit species with large individual ranges. Most of the most threatened species tend to be mammals, turtles and seabirds that may travel long distances. Even though they may not spend all their lives in an MPA, their time there can reduce mortality. Indeed, Marine Reserves have been found to protect pelagic fish and larger reserves to be more protective (Edgar et al., 2014). Thus papers in this journal have considered the role of protected areas for marine mammals, turtles, and birds (Table 2). A recent Special Issue of this journal (volume 156) on "Seabirds and Marine Protected Areas planning" contained 15 papers (Table 2). Although fewer fish and invertebrates are threatened with extinction, papers have also addressed the use of MPA for sharks, tuna, giant clams, and corals (Table 2). However, the primary consideration for large megafauna is to reduce mortality rates, for example due to reduce entanglement in fishing gear or ship strikes (Lewison et al., 2004). Because these species survival may be compromised if fisheries alter their food web, a more ecosystem based approach to their conservation is required. Thus Marine Reserves are also necessary to assess how particular species can survive in more natural ecosystems,

Table 1
Examples of where fished populations have shown significant increases within Marine Reserves compared to areas outside and/or prior to being a reserve.

Location	Publication
Africa	McClanahan et al. (1999), McClanahan (2000), Branch and Odendaal (2003), Cole et al. (2011)
Australia	Pillans et al. (2005, 2007); Barrett et al. (2009), Coleman et al. (2013), McCook et al. (2010), Curley et al. (2013)
Azores	Afonso et al. (2011)
Canary Islands	Claudet et al. (2008)
Caribbean	Hawkins and Roberts (2004), Hawkins et al. (2006)
China	Lau et al. (2011)
Hawaii	Williams et al. (2009)
Indonesia	Polunin et al. (1983)
Mediterranean	Claudet et al. (2006, 2008), Stelzenmüller et al. (2007), Guidetti (2006a,b), Guidetti et al. (2008), Harmelin-Vivien et al. (2008), Parravicini et al. (2010), Libralato et al. (2010)
New Zealand	Kelly et al. (2000), Langlois et al. (2006), Davidson and Richards (2013), Davidson et al. (2013), Smith et al. (2014)
North America	Micheli et al. (2008), Rogers-Bennett et al. (2013)
Philippines	Samoilys et al. (2007)
Seychelles	Jennings et al. (1996)
Solomon Islands	Hamilton et al. (2011, 2012)
South America	Floeter et al. (2006)

Table 2
Examples of studies published in *Biological Conservation* that considered the role of protected areas for particular species.

Species	Publications
Birds	Anderson et al. (2003), Skov et al. (2007); Trebilco et al. (2008), Wilson et al. (2009), Hazlitt et al. (2010), Velando and Munilla (2011), Chivers et al. (2013), Special Issue: Adams et al. (2012), Arcos et al. (2012), Ballard et al. (2012), Camphuysen et al. (2012), Garthe et al. (2012), Grecian et al. (2012), Lascelles et al. (2012), Le Corre et al. (2012), Ludynia et al. (2012), Montevecchi et al. (2012), O'Brien et al. (2012), Oppel et al. (2012), Pichegru et al. (2012), Ronconi et al. (2012), Thaxter et al. (2012), Péron et al. (2013)
Corals	Edinger and Risk (2000), Beger et al. (2003), Linares et al. (2008), Knittweis and Wolff (2010), Howell et al. (2011)
Giant clams	Andrefouet et al. (2013), Waters et al. (2013)
Mammals	Hooker et al. (2002), Gucu et al. (2004), Preen (2004), Vincent et al. (2005), Williams et al. (2006, 2009), Embling et al. (2010), Wiley et al. (2011), Alves et al. (2013), Bauduin et al. (2013)
Sharks	Knip et al. (2012)
Tuna	Gruss et al. (2011), Machado-Schiaffino et al. (2011), Trebilco et al. (2011)
Turtles	Zbinden et al. (2007), Witt et al. (2009), Schofield et al. (2010, 2013), Alves et al. (2013), Hart et al. (2013)

Table 3
A summary of key findings from Marine Reserves adapted from Ballantine (2014).

Socio-economic
- People enjoy them and learn at firsthand what more natural marine ecosystems are like. People have a limited frame of reference for what is natural. Marine Reserves provide this reference
- People understand marine ecosystems better, and can relate to the need for conservation in other places
- Marine Reserves attract tourists, local and international, and benefit the local economy
- Opposition occurs whenever Marine Reserves are proposed from special interest groups who have had the privilege of access to this public resource and do not understand or believe the benefits, or wish to recognise the public interest; but after reserves are established and the public witness the recovery of species and enjoy experiencing it, there is virtually unanimous public support for reserves
- With community support, the public, local fishermen and research scientists, quickly report people breaking the rules
- The line of crayfish pots and line fishing at the boundaries of Marine Reserves show that people know there is higher abundance of animals inside reserves
- Marine Reserves do not have to be only in the most remote, pristine, beautiful or diverse areas
- Some Marine Reserves should be established near major cities so the public can appreciate and learn from them
- The government provides the legal framework and management support for Marine Reserves, and the local community can benefit from it; so both government and local support is needed to establish and maintain reserves

Ecological
- Fish and lobster numbers increase in reserves faster than expected by local recruitment, suggesting a change in animal behaviour
- Fish behaviour changes in Marine Reserves; they lose their fear of people and can become more residential compared to fish outside
- Partial-take MPA attract fishing and lead to similar loss of biodiversity as unprotected areas
- Indirect impacts of fishing (i.e. trophic cascades) on benthic communities and thus habitat structure were not predicted
- Future ecological changes in Marine Reserves may yet occur, such as due to the recovery of large predatory mammals and fish, but can only be speculated
- In contrast to land reserves, no management intervention is needed for Marine Reserves to recover to a natural state (so called 're-wilding'); species colonise and adjust their abundances naturally
- Detailed scientific data is not a prerequisite to establish Marine Reserves, although irreplaceable for studying changes over time
- Marine Reserves are essential control areas for the scientific understanding of ecosystems, including the effects of climate change
- Marine Reserves could provide valuable reference sites for management of coastal resources

regardless of whether the species is sedentary or highly mobile, or its dispersal ability during its life-cycle. It is encouraging to see some very large MPA being established which may include large no-take areas (IUCN and UNEP-WCMC 2012, Leenhardt et al., 2013).

2. Role of Marine Reserves in conservation science

It may seem radical in many countries not to allow some 'take' from parts of the sea on a permanent basis. In part, this may be because people, including some scientists and policy makers, underestimate the direct and indirect effects of fishing on marine ecosystems (Pauly et al., 2005). Yet, the public has restricted access to many marine areas already, such as oil and gas exploration sites, waste disposal sites, pipeline routes, fish farms, and military areas (Ballantine, 2014). In contrast, Marine Reserves can guarantee and facilitate public access but only occupy <1% of the world's oceans (IUCN and UNEP-WCMC 2012, Leenhardt et al., 2013). In New Zealand, coastal Marine Reserves, although 32 in number, occupy just 0.2% of the coastal seabed area because most are small in size. However, the New Zealand public considered that 36% of the coastal sea area should be in reserves and (mistakenly) believed that 31% already was (Eddy, 2014). Thus public perceptions contrast with reality. With the designation of three new offshore island's this year, the area of New Zealand's Territorial Sea in Marine Reserves is now 9.5% (Freeman, personal communication).

While science can advise on the location and boundaries of Marine Reserves, having a lot of data is obviously not a prerequisite because most reserves in New Zealand (and probably globally) lacked a species inventory, and only a few have habitat maps. Thus there was little prior documentation of what species occurred in reserves and their habitats. Goat Island is an exception, with over 1053 species recorded there, and being the type locality for 46 species plus 21 found nearby (Gordon and Ballantine, 2013). Similarly, the first Marine Reserve in Ireland, Lough Hyne, was a focus of scientific attention with over 200 publications (Costello and Holmes, 1991; Costello and Myers, 1991; Myers et al., 1991). Ideally, each reserve and neighbouring areas should have a map of seabed habitats, species inventory, and data on the (a) relative abundance of the most conspicuous and any endangered species, (b) environmental context (e.g. temperature regime, sedimentation, pollution if any), and (c) previous and nearby fishing effort.

Protecting remote areas before they become heavily fished is very important (McCauley et al., 2013), such as the Marine Reserves of the Antipodes, Auckland, Bounty, Campbell, Kermadec Islands off New Zealand. Thus efforts to protect areas beyond

Please cite this article in press as: Costello, M.J. Long live Marine Reserves: A review of experiences and benefits. Biol. Conserv. (2014), http://dx.doi.org/10.1016/j.biocon.2014.04.023

national jurisdiction must also be pursued (Ardron et al., 2014). However, having some reserves accessible to the public is critical to enable public appreciation of fishing effects, and this can also benefit tourism and science.

Ballantine's (2014) review of the New Zealand experience merits reflection regarding MPA science and governments' conservation policies (Table 3). If most MPA allow some take then they are not conserving species, communities and biodiversity in a natural condition. Even if some species are protected against hunting and fishing, can these species thrive if their ecosystem is being altered? Will it be realised that their ecosystem has been altered in the absence of a Marine Reserve? It thus seems that whether intentionally or not, most MPA are either more about natural resource management than conservation, or a compromise to those who want to 'take'. Certainly, there seems little difference in practice between some areas managed under fisheries regulations and MPA (Penn and Fletcher, 2010; Spalding et al., 2013). Indeed, the definition of MPA is so broad (Day et al., 2012; Eddy, 2013; Spalding et al., 2013) that one could argue that all the world's ocean is an MPA considering efforts to reduce inputs of toxic chemicals, nuclear wastes, mortality of marine mammals and seabirds, and overfishing. While it seems that some conservationists may consider that any kind of MPA may be better than nothing, the term sends misleading messages. Only Marine Reserves are truly about conservation of biodiversity (i.e. from species' populations to ecosystems). Although the studies cited here and the IUCN MPA guidelines recognise that any take will alter biodiversity from species to ecosystems, all but one of the seven IUCN categories of MPA allow at least take by local "indigenous" communities (Day et al., 2012). In addition, sport fishing is either allowed or not prevented in most MPA (Chiappone et al., 2005; Guidetti et al., 2008; Dulvy, 2013; Eddy, 2013). Such 'take' may similarly alter food webs and ecosystems as commercial fishing and deplete populations from local to global scales. For example, the increased hunting of marine mammals (and species thereof) by local communities is endangering species globally (Pompa et al., 2011; Costello and Baker, 2011, Robards and Reeves, 2011). Pinnegar and Engelhard (2008) review examples of how artisanal fishing altered the structure of fished populations even thousands of years ago.

Without Marine Reserves, science is compromised if comparing partial-take MPA with areas with more or less restricted fishing and other impacts. However, science may benefit from a combination of Marine Reserves and strictly controlled take-MPA. Marine Reserves provide the control sites for comparison with the fished areas. This will also be important in climate change science. For example, fished and non-fished (Marine Reserve) areas showed different responses of communities to sea temperature change over 20 years (Bates et al., 2014). Thus both science and biodiversity (including fisheries) conservation need Marine Reserves rather than more ambiguous 'MPA'. At a minimum, reserves need to be replicated geographically and represent the range of species and habitats in the region for both conservation and scientific reasons (e.g. Vanderklift et al., 1998; Turpie et al., 2000; Beger et al., 2003; Carr et al., 2003; Gerber et al., 2002; Gerber and Heppell, 2004; Langlois and Ballantine, 2005; Fox and Beckley, 2005; Mumby, 2006; Salomon et al., 2006; Baskett et al., 2007, Partnership for Interdisciplinary Studies of Coastal Oceans 2007, Tognelli et al., 2005, 2009; Edwards et al., 2010; Claudet, 2011; Giakoumi et al., 2011; Hansen et al., 2011; Moffitt et al., 2011; Olsen et al., 2013; Teh et al., 2013). In doing so, Marine Reserves can restore biodiversity and provide unique social, educational and economic benefits.

Acknowledgments

I thank Annelies Struijcken for the use of the photograph in Fig. 1, and Bill Ballantine, Joachim Claudet, Debbie Freeman, Tim Langlois, Carolyn Lundquist, Alison MacDiarmid, Samara Nicholas, Pamela Mace, Richard Taylor, and Kathy Walls for helpful comments that improved this paper.

References

Adams, J., MacLeod, C., Suryan, R.M., Hyrenbach, D.K., Harvey, J.T., 2012. Summer-time use of west coast US National Marine Sanctuaries by migrating sooty shearwaters (*Puffinus griseus*). Biol. Conserv. 156, 105–116.

Afonso, P., Fontes, J., Santos, R.S., 2011. Small marine reserves can offer long term protection to an endangered fish. Biol. Conserv. 144, 2739–2744.

Alves, M.D.D.O., Schwamborn, R., Borges, J.C.G., Marmontel, M., Costa, A.F., Schettini, C.A.F., Araujo, M.E.D., 2013. Aerial survey of manatees, dolphins and sea turtles off northeastern Brazil: Correlations with coastal features and human activities. Biol. Conserv. 161, 91–100.

Anderson, D.J., Huyvaert, K.P., Wood, D.R., Gillikin, C.L., Frost, B.J., Mouritsen, H., 2003. At-sea distribution of waved albatrosses and the Galápagos Marine Reserve. Biol. Conserv. 110, 367–373.

Andrefouet, S., Van Wynsberge, S., Gaertner-Mazouni, N., Menkes, C., Gilbert, A., Remoissenet, G., 2013. Climate variability and massive mortalities challenge giant clam conservation and management efforts in French Polynesia atolls. Biol. Conserv. 160, 190–199.

Arcos, J.M., Becares, J., Villero, D., Brotons, L., Rodriguez, B., Ruiz, A., 2012. Assessing the location and stability of foraging hotspots for pelagic seabirds: an approach to identify marine Important Bird Areas (IBAs) in Spain. Biol. Conserv. 156, 30–42.

Ardron, J.A., Rayfuse, R., Gjerde, K., Warner, R., 2014. The sustainable use of biodiversity in ABNJ: what can be achieved using existing international agreements? Marine Policy. <http://dx.doi.org/10.1016/j.marpol.2014.02.011>.

Babcock, R.C., 2013. Leigh marine laboratory contributions to marine conservation. NZ J. Mar. Freshwat. Res. 47 (3), 360–373.

Baker, C.S., Clapham, P.J., 2004. Modelling the past and future of whales and whaling. Trends Ecol. Evol. 19 (7), 365–371.

Ballantine, W.J., 2014. Fifty years on: lessons from Marine Reserves in New Zealand and principles for a worldwide network. Biological Conservation (this issue). http://dx.doi.org/10.1016/j.biocon.2014.01.014.

Ballantine, W.J., Gordon, D.P., 1979. New Zealand's first marine reserve, Cape Rodney to Okakari point, Leigh. Biol. Conserv. 15, 273–280.

Ballard, G., Jongsomjit, D., Veloz, S.D., Ainley, D.G., 2012. Coexistence of mesopredators in an intact polar ocean ecosystem: The basis for defining a Ross Sea marine protected area. Biol. Conserv. 156, 72–82.

Banks, S.A., Skilleter, G.A., 2007. The importance of incorporating fine-scale habitat data into the design of an intertidal marine reserve system. Biol. Conserv. 138, 13–29.

Barrett, N., Buxton, C., Gardner, C., 2009. Rock lobster movement patterns and population structure within a Tasmanian Marine Protected Area inform fishery and conservation management. Mar. Freshwater Res. 60, 417–425.

Baskett, M.L., Micheli, F., Levin, S.A., 2007. Designing marine reserves for interacting species: insights from theory. Biol. Conserv. 137, 163–179.

Bates, A.E., Barrett, N.S., Stuart-Smith, R.D., Holbrook, N.J., Thompson, P.A., Edgar, G.J., 2014. Resilience and signatures of tropicalization in protected reef fish communities. Nat. Clim. Change 4, 62–67. http://dx.doi.org/10.1038/nclimate2062.

Bauduin, S., Martin, J., Edwards, H.H., Gimenez, O., Koslovsky, S.M., Fagan, D.E., 2013. An index of risk of co-occurrence between marine mammals and watercraft: example of the Florida manatee. Biol. Conserv. 159, 127–136.

Beger, M., Jones, G.P., Munday, P.L., 2003. Conservation of coral reef biodiversity: a comparison of reserve selection procedures for corals and fishes. Biol. Conserv. 111, 53–62.

Bo, M., Bava, S., Canese, S., Angiolillo, M., Cattaneo-Vietti, R., Bavestrello, G., 2014. Fishing impact on deep Mediterranean rocky habitats as revealed by ROV investigation. Biol. Conserv. 171, 167–176.

Botsford, L.W., Castilla, J.C., Peterson, C.H., 2004. The management of fisheries and marine ecosystems. Science 277, 509–515.

Branch, G.M., Odendaal, F., 2003. The effects of Marine Protected Areas on the population dynamics of a South African limpet, *Cymbula oculus*, relative to the influence of wave action. Biol. Conserv. 114, 255–269.

Camphuysen, K.C.J., Shamoun-Baranes, J., Bouten, W., Garthe, S., 2012. Identifying ecologically important marine areas for seabirds using behavioural information in combination with distribution patterns. Biol. Conserv. 156, 22–29.

Carr, M.H., Neigel, J.E., Estes, J.A., Andelman, S., Warner, R.R., Largier, J.L., 2003. Comparing marine and terrestrial ecosystems: implications for the design of coastal marine reserves. Ecol. Appl. 13, 90–107.

Chiappone, M., Dienes, H., Swanson, D.W., Miller, S.L., 2005. Impacts of lost fishing gear on coral reef sessile invertebrates in the Florida Keys National Marine Sanctuary. Biol. Conserv. 121, 221–230.

Chivers, L.S., Lundy, M.G., Colhoun, K., Newton, S.F., Houghton, J.D.R., Reid, N., 2013. Identifying optimal feeding habitat and proposed Marine Protected Areas (pMPAs) for the black-legged kittiwake (*Rissa tridactyla*) suggests a need for complementary management approaches. Biol. Conserv. 164, 73–81.

Claudet, J. (Ed.), 2011. Marine Protected Areas: A Multidisciplinary Approach. Cambridge University Press, p. 377.

Claudet, J., Guidetti, P., 2010. Fishermen contribute to protection of marine reserves. Nature 464 (7289), 673.

Claudet, J., Pelletier, D., Jouvenel, J.-Y., Bachet, F., Galzin, R., 2006. Assessing the effects of marine protected area (MPA) on a reef fish assemblage in a northwestern Mediterranean marine reserve: identifying community-based indicators. Biol. Conserv. 130, 349–369.

Claudet, J., Osenberg, C.W., Benedetti-Cecchi, L., Domenici, P., Garcia-Charton, J.-A., Pérez-Ruzafa, Á., Badalamenti, F., Bayle-Sempere, J., Brito, A., Bulleri, F., Culioli, J.-M., Dimech, M., Falcón, J.M., Guala, I., Milazzo, M., Sánchez-Meca, J., Somerfield, P.J., Stobart, B., Vandeperre, F., Valle, C., Planes, S., 2008. Marine reserves: size and age do matter. Ecol. Lett. 11, 481–489.

Cocklin, C., Craw, M., Mcauley, I., 1998. Marine reserves in New Zealand: use rights, public attitudes, and social impacts. Coastal Manage. 26 (3), 213–231. http://dx.doi.org/10.1080/08920759809362353.

Cole, R.G., 1994. Abundance, size structure, and diver-oriented behaviour of three large benthic carnivorous fishes in a marine reserve in northeastern New Zealand. Biol. Conserv. 70, 93–99.

Cole, V.J., McQuaid, C.D., Nakin, M.D.V., 2011. Marine Protected Areas export larvae of in fauna, but not of bioengineering mussels to adjacent areas. Biol. Conserv. 144, 2088–2096.

Coleman, M.A., Palmer-Brodie, A., Kelaher, B.P., 2013. Conservation benefits of a network of marine reserves and partially protected areas. Biol. Conserv. 167, 257–264.

Cook, S.J., Danylchuk, A.J., Danylchuk, S.E., Suski, C.D., Goldberg, T.L., 2006. Is catch-and-release recreational angling compatible with no-take Marine Protected Areas? Ocean Coast. Manag. 49, 342–354.

Costello, M.J., Baker, C.S., 2011. Who eats sea meat? Expanding human consumption of marine mammals. Biol. Conserv. 144, 2745–2746.

Costello, M.J., Holmes, J.M.C., 1991. Bibliography of Lough Hyne to 1990. In: Myers, A.A., Little, C., Costello, M.J., Partridge, J.C. (Eds.), The Ecology of Lough Hyne: Proceedings of a Conference 4-September 1990. Royal Irish Academy, Dublin, pp. 171–175.

Costello, M.J., Myers, A.A., 1991. The biogeographic richness of the Amphipoda. In: Myers, A.A., Little, C., Costello, M.J., Partridge, J.C. (Eds.), The Ecology of Lough Hyne: Proceedings of a Conference 4-September 1990. Royal Irish Academy, Dublin, pp. 157–162.

Cullis-Suzuki, S., Pauly, D., 2010. Marine protected area costs as "beneficial" fisheries subsidies: a global evaluation. Coastal Manage. 38 (2), 113–121.

Curley, B.G., Glasby, T.M., Curley, A.J., Creese, R.G., Kingsford, M.J., 2013. Enhanced numbers of two temperate reef fishes in a small, partial-take marine protected area related to spearfisher exclusion. Biol. Conserv. 167, 435–445.

Davidson, R.J., Richards, L.A., 2013. Tonga Island Marine Reserve, Abel Tasman National Park: update of biological monitoring, 1993–2013. Department of Conservation, Nelson. Survey and Monitoring, Report No. 771, p. 68.

Davidson, R.J., Richards, L.A., Bayly, S., Devries, D., Bodin, G., LaFerriere, A., Fowler, S., 2013. Horoirangi Marine Reserve, North Nelson, report on rocky shore biological monitoring, 2006–2013. Department of Conservation, Nelson. Survey and Monitoring Report No. 694, p. 52.

Davies, A.J., Roberts, J.M., Hall-Spencer, J., 2007. Preserving deep-sea natural heritage: Emerging issues in offshore conservation and management. Biol. Conserv. 138, 299–312.

Day, J., Dudley, N., Hockings, M., Holmes, G., Laffoley, D., Stolton, S., Wells, S., 2012. Guidelines for applying the IUCN Protected Area Management Categories to Marine Protected Areas. IUCN, Gland, Switzerland, 36pp.

Denny, C.M., Babcock, R.C., 2004. Do partial marine reserves protect reef fish assemblages? Biol. Conserv. 116, 119–129.

Denny, C.M., Willis, T.J., Babcock, R.C., 2004. Rapid recolonisation of snapper *Pagrus auratus*: Sparidae within an offshore island marine reserve after implementation of no-take status. Mar. Ecol. Prog. Ser. 272, 183–190.

Di Franco, A., Bussotti, S., Navone, A., Panzalis, P., Guidetti, P., 2009. Evaluating effects of total and partial restrictions to fishing on Mediterranean rocky-reef fish assemblages. Mar. Ecol. Prog. Ser. 387, 275–285.

Doak, W., 2006. Poor Knights reason to celebrate. Dive New Zealand 92, 28–29.

Dulvy, N.K., 2013. Super-sized MPAs and the marginalisation of species conservation. Aquat. Conserv.: Marine Freshwater Ecosyst. 23 (3), 357–362.

Eddy, T.D., 2013. On the need for meaningful marine protected area (MPA) standards. Aquat. Conserv.: Marine Freshwater Ecosyst. 23 (4), 481–482.

Eddy, T.D., 2014. One hundred-fold difference between perceived and actual levels of marine protection in New Zealand. Marine Policy 46, 61–67.

Edgar, G.J., Stuart-Smith, R.D., Willis, T.J., Kininmonth, S., Baker, S.C., Banks, S., et al., 2014. Global conservation outcomes depend on Marine Protected Areas with five key features. Nature 506, 216–220.

Edinger, E.N., Risk, M.J., 2000. Reef classification by coral morphology predicts coral reef conservation value. Biol. Conserv. 92, 1–13.

Edwards, H.J., Elliott, I.A., Pressey, R.L., Mumby, P.J., 2010. Incorporating ontogenetic dispersal, ecological processes and conservation zoning into reserve design. Biol. Conserv. 143, 457–470.

Embling, C.B., Gillibrand, P.A., Gordon, J., Shrimpton, J., Stevick, P.T., Hammond, P.S., 2010. Using habitat models to identify suitable sites for Marine Protected Areas for harbour porpoises (*Phocoena phocoena*). Biol. Conserv. 143, 267–279.

Floeter, S.R., Halpern, B.S., Ferreira, C.E.L., 2006. Effects of fishing and protection on Brazilian reef fishes. Biol. Conserv. 128, 391–402.

Fox, N.J., Beckley, L.E., 2005. Priority areas for conservation of Western Australian coastal fishes: a comparison of hotspot, biogeographical and complementarity approaches. Biol. Conserv. 125, 399–410.

Garthe, S., Markones, N., Mendel, B., Sonntag, N., Krause, J.C., 2012. Protected areas for seabirds in German offshore waters: designation, retrospective consideration and current perspectives. Biol. Conserv. 156, 126–135.

Gerber, L.R., Heppell, S.S., 2004. The use of demographic sensitivity analysis in marine species conservation planning. Biol. Conserv. 120, 121–128.

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

Giakoumi, S., Grantham, H.S., Kokkoris, G.D., Possingham, H.P., 2011. Designing a network of marine reserves in the Mediterranean Sea with limited socio-economic data. Biol. Conserv. 144, 753–763.

Gordon, D.P., Ballantine, B., 2013. Contribution to the Leigh Marine Laboratory to knowledge of marine species diversity. NZ J. Mar. Freshwat. Res. 47 (3), 277–293.

Grace, R., 2006. The amazing Poor Knights. Dive New Zealand 92, 25–227.

Grecian, W.J., Witt, M.J., Attrill, M.J., Bearhop, S., Godley, B.J., Gremillet, D., Hamer, K.C., Votier, S.C., 2012. A novel projection technique to identify important at-sea areas for seabird conservation: an example using Northern gannets breeding in the North East Atlantic. Biol. Conserv. 156, 43–52.

Gruss, A., Kaplan, D.M., Guenette, S., Roberts, C.M., Botsford, L.W., 2011. Consequences of adult and juvenile movement for Marine Protected Areas. Biol. Conserv. 144, 692–702.

Gucu, A.C., Gucu, G., Orek, H., 2004. Habitat use and preliminary demographic evaluation of the critically endangered Mediterranean monk seal (*Monachus monachus*) in the Cilician Basin (Eastern Mediterranean). Biol. Conserv. 116, 417–431.

Guidetti, P., 2006a. Potential of marine reserves to cause community-wide changes beyond their boundaries. Conserv. Biol. 21, 540–545.

Guidetti, P., 2006b. Marine reserves reestablish lost predatory interactions and cause community changes in rocky reefs. Ecol. Appl. 16, 963–976.

Guidetti, P., Milazzo, M., Bussotti, S., Molinari, A., Murenu, M., Pais, A., Spano, N., Balzano, R., Agardy, T., Boero, F., Carrada, G., Cattaneo-Vietti, R., Cau, A., Chemello, R., Greco, S., Manganaro, A., Notarbartolo di Sciara, G., Russo, G.F., Tunesi, L., 2008. Italian marine reserve effectiveness: does enforcement matter? Biol. Conserv. 141, 699–709.

Hamilton, R.J., Potuku, T., Montambault, J.R., 2011. Community-based conservation results in the recovery of reef fish spawning aggregations in the Coral Triangle. Biol. Conserv. 144, 1850–1858.

Hamilton, R.J., Giningele, M., Aswani, S., Ecochard, J.L., 2012. Fishing in the dark-local knowledge, night spearfishing and spawning aggregations in the Western Solomon Islands. Biol. Conserv. 145, 246–257.

Hansen, G.J.A., Ban, N.C., Jones, M.L., Kaufman, L., Panes, H.M., Yasue, M., Vincent, A.C.J., 2011. Hindsight in marine protected area selection: a comparison of ecological representation arising from opportunistic and systematic approaches. Biol. Conserv. 144, 1866–1875.

Harmelin-Vivien, M., Le Direach, L., Bayle-Sempere, J., Charbonnel, E., Garcia-Charton, J.A., Ody, D., Perez-Ruzafa, A., Renones, O., Sanchez-Jerez, P., Valle, C., 2008. Gradients of abundance and biomass across reserve boundaries in six Mediterranean Marine Protected Areas: evidence of fish spillover? Biol. Conserv. 141, 1829–1839.

Hart, K.M., Zawada, D.G., Fujisaki, I., Lidz, B.H., 2013. Habitat use of breeding green turtles *Chelonia mydas* tagged in Dry Tortugas National Park: making use of local and regional MPAs. Biol. Conserv. 161, 142–154.

Hathaway, S., 2009. Marine Reserve Human Chain <http://www.youtube.com/watch?v=9GAWmkpLwO8> (accessed 06.01.14).

Hawkins, J.P., Roberts, C.M., 2004. Effects of fishing on sex-changing Caribbean parrotfishes. Biol. Conserv. 115, 213–226.

Hawkins, J.P., Roberts, C.M., Dytham, C., Schelten, C., Nugues, M.M., 2006. Effects of habitat characteristics and sedimentation on performance of marine reserves in St. Lucia. Biol. Conserv. 127, 487–499.

Hazlitt, S.L., Martin, T.G., Sampson, L., Arcese, P., 2010. The effects of including marine ecological values in terrestrial reserve planning for a forest-nesting seabird. Biol. Conserv. 143, 1299–1303.

Hooker, S.K., Whitehead, H., Gowans, S., 2002. Ecosystem consideration in conservation planning: Energy demand of foraging bottlenose whales (*Hyperoodon ampullatus*) in a marine protected area. Biol. Conserv. 104, 51–58.

Howell, K.L., 2010. A benthic classification system to aid in the implementation of marine protected area networks in the deep/high seas of the NE Atlantic. Biol. Conserv. 143, 1041–1056.

Howell, K.L., Holt, R., Endrino, I.P., Stewart, H., 2011. When the species is also a habitat: comparing the predictively modelled distributions of *Lophelia pertusa* and the reef habitat it forms. Biol. Conserv. 144, 2656–2665.

Hunt, L., 2008. Economic Impact Analysis of the Cape Rodney Okakari Point (Leigh) Marine Reserve on the Rodney District. Investigation number 4052 A report prepared for the Department of Conservation, New Zealand. <http://www.marinenz.org.nz/documents/leigh_eco_impact.pdf> (accessed on 08.01.14).

IUCN and UNEP-WCMC, 2012. The World Database on Protected Areas (WDPA). Cambridge, UK: UNEP-WCMC. <www.protectedplanet.net> (accessed on September 2012).

Jackson, J.B., Kirby, M.X., Berger, W.H., Bjorndal, K.A., Botsford, L.W., Bourque, B.J., Bradbury, R.H., Cooke, R., Erlandson, J., Estes, J.A., Hughes, T.P., Kidwell, S., Lange, C.B., Lenihan, H.S., Pandolfi, J.M., Peterson, C.H., Steneck, R.S., Tegner, M.J., Warner, R.R., 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science 293 (5530), 629–637.

Jennings, S., Marshall, S.S., Polunin, N.V.C., 1996. Seychelles' Marine Protected Areas: comparative structure and status of reef fish communities. Biol. Conserv. 75, 201–209.

Kelly, S., Scott, D., MacDiarmid, A.B., Babcock, R.C., 2000. Spiny lobster, *Jasus edwardsii*, recovery in New Zealand Marine Reserves. Biol. Conserv. 92, 359–369.
Kelly, S., Scott, D., MacDiarmid, A.B., 2002. The value of a spillover fishery for spiny lobsters around a marine reserve in Northern New Zealand. Coastal Manage. 30 (2), 153–166.
Knip, D.M., Heupel, M.R., Simpfendorfer, C.A., 2012. Evaluating Marine Protected Areas for the conservation of tropical coastal sharks. Biol. Conserv. 148, 200–209.
Knittweis, L., Wolff, M., 2010. Live coral trade impacts on the mushroom coral *Heliofungia actiniformis* in Indonesia: potential future management approaches. Biol. Conserv. 143, 2722–2729.
Langlois, T.J., Ballantine, W.J., 2005. Marine ecological research in New Zealand: developing predictive models through the study of no-take marine reserves. Conserv. Biol. 19 (6), 1763–1770.
Langlois, T.J., Anderson, M.J., Babcock, R.C., Kato, S., 2006. Marine reserves demonstrate trophic interactions across habitats. Oecologia 147, 134–140.
Lascelles, B.G., Langham, G.M., Ronconi, R.A., Reid, J.B., 2012. From hotspots to site protection: identifying Marine Protected Areas for seabirds around the globe. Biol. Conserv. 156, 5–14.
Lau, D.C.C., Dumont, C.P., Lui, G.C.S., Qiu, J.-W., 2011. Effectiveness of a small marine reserve in southern China in protecting the harvested sea urchin *Anthocidaris crassispina*: a mark-and-recapture study. Biol. Conserv. 144, 2674–2683.
Le Corre, M., Jaeger, A., Pinet, P., Kappes, M.A., Weimerskirch, H., Catry, T., Ramos, J.A., Russell, J.C., Shah, N., Jaquemet, S., 2012. Tracking seabirds to identify potential Marine Protected Areas in the tropical western Indian Ocean. Biol. Conserv. 156, 83–93.
Leenhardt, P., Cazalet, B., Salvat, B., Claudet, J., Feral, F., 2013. The rise of large-scale Marine Protected Areas: conservation or geopolitics? Ocean Coast. Manage. 85, 112–118.
Leleu, K., Remy-Zephir, B., Grace, R., Costello, M.J., 2012. Mapping habitat change after 30 years in a marine reserve shows how fishing can alter ecosystem structure. Biol. Conserv. 155, 193–201.
Lester, S.E., Halpern, B.S., 2008. Biological responses in marine no-take reserves versus partially protected areas. Mar. Ecol. Prog. Ser. 367, 49–56.
Lewison, R.L., Crowder, L.B., Read, A.J., Freeman, S.A., 2004. Understanding impacts of fisheries bycatch on marine megafauna. Trends Ecol. Evol. 19 (11), 598–604.
Libralato, S., Coll, M., Tempesta, M., Santojanni, A., Spoto, M., Palomera, I., Arneri, E., Solidoro, C., 2010. Food-web traits of protected and exploited areas of the Adriatic Sea. Biol. Conserv. 143, 2182–2194.
Linares, C., Coma, R., Zabala, M., 2008. Restoration of threatened red gorgonian populations: an experimental and modelling approach. Biol. Conserv. 141, 427–437.
Lotze, H.K., Lenihan, H.S., Bourque, B.J., Bradbury, R.H., Cooke, R.G., Kay, M.C., Kidwell, S.M., Kirby, M.X., Peterson, C.H., Jackson, J.B., 2006. Depletion, degradation, and recovery potential of estuaries and coastal seas. Science 312 (5781), 1806–1809.
Ludynia, K., Kemper, J., Roux, J.-P., 2012. The Namibian Islands' Marine Protected Area: using seabird tracking data to define boundaries and assess their adequacy. Biol. Conserv. 156, 136–145.
Machado-Schiaffino, G., Juanes, F., Garcia-Vazquez, E., 2011. Identifying unique populations in long-dispersal marine species: Gulfs as priority conservation areas. Biol. Conserv. 144, 330–338.
McCauley, D.J., Power, E.A., Bird, D.W., McInturff, A., Dunbar, R.B., Durham, W.H., et al., 2013. Conservation at the edge of the world. Biol. Conserv. 165, 139–145.
McClanahan, T.R., 2000. Recovery of a coral reef keystone predator, *Balistapus undulatus*, in East African marine parks. Biol. Conserv. 94, 191–198.
McClanahan, T.R., Muthiga, N.A., Kamukuru, A.T., Machano, H., Kiambo, R.W., 1999. The effects of marine parks and fishing on coral reefs of northern Tanzania. Biol. Conserv. 89, 161–182.
McCook, L.J., Ayling, T., Cappo, M., Choat, J.H., Evans, R.D., De Freitas, D.M., Heupel, M., Hughes, T.P., Jones, G.P., Mapstone, B., Marsh, H., Mills, M., Molloy, F.J., Pitcher, C.R., Pressey, R.L., Russ, G.R., Sutton, S., Sweatman, H., Tobin, R., Wachenfeld, D.R., Williamson, D.H., 2010. Adaptive management of the Great Barrier Reef: a globally significant demonstration of the benefits of networks of marine reserves. Proc. Natl. Acad. Sci. USA 107 (43), 18278–18285.
Micheli, F., Shelton, A.O., Bushinsky, S.M., Chiu, A.L., Haupt, A.J., Heiman, K.W., Kappel, C.V., Lynch, M.C., Martone, R.G., Dunbar, R.B., Watanabe, J., 2008. Persistence of depleted abalones in marine reserves of central California. Biol. Conserv. 141, 1078–1090.
Moffitt, E.A., Wilson White, J., Botsford, L.W., 2011. The utility and limitations of size and spacing guidelines for designing marine protected area (MPA) networks. Biol. Conserv. 144, 306–318.
Molloy, P.P., Reynolds, J.D., Gage, M.J.G., Mosqueira, I., Cote, I.M., 2008. Links between sex change and fish densities in Marine Protected Areas. Biol. Conserv. 141, 187–197.
Molloy, P.P., McLean, I.B., Côté, I.M., 2009. Effects of marine reserve age on fish populations: a global meta-analysis. J. Appl. Ecol. 46, 743–751.
Montevecchi, W.A., Hedd, A., McFarlane Tranquilla, L., Fifield, D.A., Burke, C.M., Regular, P.M., Davoren, G.K., Garthe, S., Robertson, G.J., Phillips, R.A., 2012. Tracking seabirds to identify ecologically important and high risk marine areas in the western North Atlantic. Biol. Conserv. 156, 62–71.
Morato, T., Watson, R., Pitcher, T.J., Pauly, D., 2006. Fishing down the deep. Fish Fish. 7, 24–34.
Mumby, P.J., 2006. Connectivity of reef fish between mangroves and coral reefs: algorithms for the design of marine reserves at seascape scales. Biol. Conserv. 128, 215–222.
Mumby, P.J., Harborne, A.R., 1999. Development of a systematic classification scheme of marine habitats to facilitate regional management and mapping of Caribbean coral reefs. Biol. Conserv. 88, 155–163.
Myers, A.A., Little, C., Costello, M.J., Partridge, J.C., (Eds.), 1991. The Ecology of Lough Hyne. In: Proceedings of a conference 4-September 1990, Royal Irish Academy, Dublin, 175pp.
Nicholas, S., Yiu, T., 2012. Experiencing Marine Reserves 10th Anniversary Charity Movie. <http://www.youtube.com/watch?v=WMWsm95bR_Y> (Accessed 06.01.14).
O'Brien, S.H., Webb, A., Brewer, M.J., Reid, J.B., 2012. Use of kernel density estimation and maximum curvature to set Marine Protected Area boundaries: identifying a Special Protection Area for wintering red-throated divers in the UK. Biol. Conserv. 156, 15–21.
Olsen, E.M., Johnson, D., Weaver, P., Goñi, R., Ribeiro, M.C., Rabaut, M., Macpherson, E., Pelletier, D., Fonseca, L., Katsanevakis, S., Zaharia, T., (2013). Achieving Ecologically Coherent MPA Networks in Europe: Science Needs and Priorities. Marine Board Position Paper 18. Larkin, KE and McDonough N (Eds.), European Marine Board, Ostend, Belgium.
Oppel, S., Meirinho, A., Ramirez, I., Gardner, B., O'Connell, A.F., Miller, P.I., Louzao, M., 2012. Comparison of five modelling techniques to predict the spatial distribution and abundance of seabirds. Biol. Conserv. 156, 94–104.
Parravicini, V., Thrush, S.F., Chiantore, M., Morri, C., Croci, C., Bianchi, C.N., 2010. The legacy of past disturbance: chronic angling impairs long-term recovery of marine epibenthic communities from acute date-mussel harvesting. Biol. Conserv. 143, 2435–2440.
Parsons, D.M., Morrison, M.A., Slater, M.J., 2010. Responses to marine reserves: decreased dispersion of the sparid *Pagrus auratus* (snapper). Biol. Conserv. 143, 2039–2048.
Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO), 2007. The Science of Marine Reserves, second ed., USA, 22pp, <www.piscoweb.org> (Accessed 23.12.13).
Pauly, D., Watson, R., Alder, J., 2005. Global trends in world fisheries: impacts on marine ecosystems and food security. Philos. Trans. R Soc. B 260, 5–12.
Penn, J., Fletcher, W., 2010. The efficacy of snactuary areas for the management of fish stocks and biodiveristy in WA waters. Fisheries Research Report No. 169, Deparment of Fisheries, Western Australia.
Péron, C., Grémillet, D., Prudor, A., Pettex, E., Saraux, C., Soriano-Redondo, A., Authier, M., Fort, J., 2013. Importance of coastal Marine Protected Areas for the conservation of pelagic seabirds: the case of vulnerable yelkouan shearwaters in the Mediterranean Sea. Biol. Conserv. 168, 210–221.
Pichegru, L., Ryan, P.G., van Eeden, R., Reid, T., Gremillet, D., Wanless, R., 2012. Industrial fishing, no-take zones and endangered penguins. Biol. Conserv. 156, 117–125.
Pillans, S., Pillans, R.D., Johnstone, R.W., Kraft, P.G., Haywood, M.D.E., Possingham, H.P., 2005. Effects of marine reserve protection on the mud crab Scylla serrata in a sex-biased fishery in subtropical Australia. Mar. Ecol. Prog. Ser. 295, 201–213.
Pillans, S., Ortiz, J.-C., Pillans, R.D., Possingham, H.P., 2007. The impact of marine reserves on nekton diversity and community composition in subtropical eastern Australia. Biol. Conserv. 136, 455–469.
Pinnegar, J.K., Engelhard, G.H., 2008. The 'shifting baseline' phenomenon: a global perspective. Rev. Fish Biol. Fisher. 18 (1), 1–16.
Polunin, N.V.C., Halim, M.K., Kvalvagnaes, K., 1983. Bali Barat: an Indonesian marine protected area and its resources. Biol. Conserv. 25, 171–191.
Pompa, S., Ehrlich, P.R., Ceballos, G., 2011. Global distribution and conservation of marine mammals. PNAS 108 (33), 13600–13605.
Preen, A., 2004. Distribution, abundance and conservation status of dugongs and dolphins in the southern and western Arabian Gulf. Biol. Conserv. 118, 205–218.
Robards, M., Reeves, R.R., 2011. The global extent and character of marine mammal consumption by humans. Biol. Conserv. 144 (12), 2770–2786.
Rogers-Bennett, L., Hubbard, K.E., Juhasz, C.I., 2013. Dramatic declines in red abalone populations after opening a "de facto" marine reserve to fishing: testing temporal reserves. Biol. Conserv. 157, 423–431.
Ronconi, R.A., Lascelles, B.G., Langham, G.M., Reid, J.B., Oro, D., 2012. The role of seabirds in marine protected area identification, delineation, and monitoring: introduction and synthesis. Biol. Conserv. 156, 1–4.
Salomon, A.K., Ruesink, J.L., DeWreede, R.E., 2006. Population viability, ecological processes and biodiversity: valuing sites for reserve selection. Biol. Conserv. 128, 79–92.
Samoilys, M.A., Martin-Smith, K.M., Giles, B.G., Cabrera, B., Anticamara, J.A., Brunio, E.O., Vincent, A.C.J., 2007. Effectiveness of five small Philippines' coral reef reserves for fish populations depends on site-specific factors, particularly enforcement history. Biol. Conserv. 136, 584–601.
Schofield, G., Hobson, V.J., Lilley, M.K.S., Katselidis, K.A., Bishop, C.M., Brown, P., Hays, G.C., 2010. Inter-annual variability in the home range of breeding turtles: implications for current and future conservation management. Biol. Conserv. 143, 722–730.
Schofield, G., Scott, R., Dimadi, A., Fossette, S., Katselidis, K.A., Koutsoubas, D., Lilley, M.K.S., Pantis, J.D., Karagouni, A.D., Hays, G.C., 2013. Evidence-based marine protected area planning for a highly mobile endangered marine vertebrate. Biol. Conserv. 161, 101–109.
Shears, N.T., Grace, R.V., Usmar, N.R., Kerr, V., Babcock, R.C., 2006. Long-term trends in lobster populations in a partially protected vs. no-take Marine Park. Biol. Conserv. 132, 222–231.
Shears, N.T., Babcock, R.C., Salomon, A., 2008. Context-dependent effects of fishing: variation in trophic cascades across environmental gradients. Ecol. Appl. 18 (8), 1860–1873.

Skov, H., Durinck, J., Leopold, M.F., Tasker, M.L., 2007. A quantitative method for evaluating the importance of marine areas for conservation of birds. Biol. Conserv. 136, 362–371.

Smith, A.N.H., Anderson, M.J., Millar, R.B., Willis, T.J., 2014. Effects of marine reserves in the context of spatial and temporal variation: an analysis using Bayesian zero-inflated mixed models. Mar. Ecol. Prog. Ser. 499, 203–216.

Spalding, M.D., Meliane, I., Milam, A., Fitzgerald, C., Hale, L.Z., 2013. Protecting marine spaces: global targets and changing approaches. In: Chircop, A., Coffen-Smout, S., McConnell, M. (Eds.), Ocean Yearbook 27. Koninklijke Brill NV Publishers, Leiden, pp. 213–248.

Springer, A.M., Estes, J.A., van Vliet, G.B., Williams, T.M., Doak, D.F., Danner, E.M., Forney, K.A., Pfister, B., 2003. Sequential megafaunal collapse in the North Pacific Ocean: an ongoing legacy of industrial whaling? PNAS 100 (21), 12223–12228.

Stelzenmüller, V., Maynou, F., Martin, P., 2007. Spatial assessment of benefits of a coastal mediterranean marine protected area. Biol. Conserv. 136, 571–583.

Stevens, T., Connolly, R.M., 2004. Testing the utility of abiotic surrogates for marine habitat mapping at scales relevant to management. Biol. Conserv. 119, 351–362.

Stevenson, T.C., Tissot, B.N., Walsh, W.J., 2013. Socioeconomic consequences of fishing displacement from Marine Protected Areas in Hawaii. Biol. Conserv. 160, 50–58.

Taylor, N., Buckenham, B., 2003. Social impacts of marine reserves in New Zealand. Sci. Conserv. 217, 58.

Taylor, R.B., Morrison, M.A., Shears, N.T., 2011. Establishing baselines for recovery in a marine reserve (Poor Knights Islands, New Zealand) using local ecological knowledge. Biol. Conserv. 144, 3038–3046.

Teh, L.C.L., Teh, L.S.L., Jumin, R., 2013. Combining human preference and biodiversity priorities for marine protected area site selection in Sabah, Malaysia. Biol. Conserv. 167, 396–404.

Thaxter, C.B., Lascelles, B., Sugar, K., Cook, A.S.C.P., Roos, S., Bolton, M., Langston, R.H.W., Burton, N.H.K., 2012. Seabird foraging ranges as a preliminary tool for identifying candidate Marine Protected Areas. Biol. Conserv. 156, 53–61.

The Allen Consulting Group, 2009. The economics of Marine Protected Areas. The Allen Consulting Group Ltd., Melbourne, Australia.

Tognelli, M.F., Silva-Garcia, C., Labra, F.A., Marquet, P.A., 2005. Priority areas for the conservation of coastal marine vertebrates in Chile. Biol. Conserv. 126, 420–428.

Tognelli, M.F., Fernandez, M., Marquet, P.A., 2009. Assessing the performance of the existing and proposed network of Marine Protected Areas to conserve marine biodiversity in Chile. Biol. Conserv. 142, 3147–3153.

Towns, D.R., Ballantine, W.J., 1993. Conservation and restoration of New Zealand island ecosystems. Trends Ecol. Evol. 8, 452–457.

Trebilco, R., Gales, R., Baker, G.B., Terauds, A., Sumner, M.D., 2008. At sea movement of Macquarie Island giant petrels: relationships with Marine Protected Areas and Regional Fisheries Management Organisations. Biol. Conserv. 141, 2942–2958.

Trebilco, R., Halpern, B.S., Flemming, J.M., Field, C., Blanchard, W., Worm, B., 2011. Mapping species richness and human impact drivers to inform global pelagic conservation prioritisation. Biol. Conserv. 144, 1758–1766.

Tulloch, V.J., Possingham, H.P., Jupiter, S.D., Roelfsema, C., Tulloch, A.I.T., Klein, C.J., 2013. Incorporating uncertainty associated with habitat data in marine reserve design. Biol. Conserv. 162, 41–51.

Turpie, J.K., Beckley, L.E., Katua, S.M., 2000. Biogeography and the selection of priority areas for conservation of South African coastal fishes. Biol. Conserv. 92, 59–72.

Vanderklift, M.A., Ward, T.J., Phillips, J.C., 1998. Use of assemblages derived from different taxonomic levels to select areas for conserving marine biodiversity. Biol. Conserv. 86, 307–315.

Velando, A., Munilla, I., 2011. Disturbance to a foraging seabird by sea-based tourism: implications for reserve management in Marine Protected Areas. Biol. Conserv. 144, 1167–1174.

Vianna, G.M.S., Meekan, M.G., Pannell, D.J., Marsh, S.P., Meeuwig, J.J., 2012. Socio-economic value and community benefits from shark-diving tourism in Palau: a sustainable use of reef shark populations. Biol. Conserv. 145, 267–277.

Vincent, C., Fedak, M.A., McConnell, B.J., Meynier, L., Saint-Jean, C., Ridoux, V., 2005. Status and conservation of the grey seal, *Halichœrus grypus*, in France. Biol. Conserv. 126, 62–73.

Walls, K., 1998. Leigh marine reserve, New Zealand. Parks 8, 5–10.

Waters, C., Storey, R., Costello, MJ., 2013. A methodology for recruiting a giant clam, *Tridacna maxima,* directly to natural substrata: a first step in reversing functional extinctions? Biol. Conserv. 160, 19–24.

Wiley, D.N., Thompson, M., Pace, R.M., Levenson, J., 2011. Modeling speed restrictions to mitigate lethal collisions between ships and whales in the Stellwagen Bank National Marine Sanctuary, USA. Biol. Conserv. 144, 2377–2381.

Williams, R., Lusseau, D., Hammond, P.S., 2006. Estimating relative energetic costs of human disturbance to killer whales (*Orcinus orca*). Biol. Conserv. 133, 301–311.

Williams, I.D., Walsh, W.J., Claisse, J.T., Tissot, B.N., Stamoulis, K.A., 2009a. Impacts of a Hawaiian marine protected area network on the abundance and fishery sustainability of the yellow tang, *Zebrasoma flavescens*. Biol. Conserv. 142, 1066–1073.

Williams, R., Lusseau, D., Hammond, P.S., 2009b. The role of social aggregations and protected areas in killer whale conservation: the mixed blessing of critical habitat. Biol. Conserv. 142, 709–719.

Wilson, L.J., McSorley, C.A., Gray, C.M., Dean, B.J., Dunn, T.E., Webb, A., Reid, J.B., 2009. Radio-telemetry as a tool to define protected areas for seabirds in the marine environment. Biol. Conserv. 142, 1808–1817.

Witt, M.J., Baert, B., Broderick, A.C., Formia, A., Fretey, J., Gibudi, A., Mounguengui, G.A.M., Moussounda, C., Ngouessono, S., Parnell, R.J., Roumet, D., Sounguet, G.-P., Verhage, B., Zogo, A., Godley, B.J., 2009. Aerial surveying of the world's largest leatherback turtle rookery: a more effective methodology for large-scale monitoring. Biol. Conserv. 142, 1719–1727.

Worm, B., Barbier, E.B., Beaumont, N., Duffy, J.E., Folke, C., Halpern, B.S., Jackson, J.B.C., Lotze, H.K., Micheli, F., Palumbi, S.R., Sala, E., Selkoe, K.A., Stachowicz, J.J., Watson, R., 2006. Impacts of biodiversity loss on ocean ecosystem services. Science 314 (5800), 787–790.

Yamazaki, S., Grafton, Q.R., Kompas, T., Jennings, S., 2012. Biomass management targets and the conservation and economic benefits of marine reserves. Fish Fish. http://dx.doi.org/10.1111/faf.12008.

Zbinden, J.A., Aebischer, A., Margaritoulis, D., Arlettaz, R., 2007. Insights into the management of sea turtle inter-nesting area through satellite telemetry. Biol. Conserv. 137, 157–162.

Please cite this article in press as: Costello, M.J. Long live Marine Reserves: A review of experiences and benefits. Biol. Conserv. (2014), http://dx.doi.org/10.1016/j.biocon.2014.04.023