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Large marine protected areas – advantages and challenges of going big

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ABSTRACT

1. The Aichi Biodiversity Targets were designed to promote and implement the Convention on Biological Diversity (CBD) by providing a framework for action to save biodiversity and enhance its benefits for people. Specifically, Target 11 aims to protect 10% of all seas by 2020. The percentage of the world's oceans that are protected has increased steadily in recent years, mainly due to very large marine protected areas (MPAs).

2. The issue of making major gains in achieving protection targets through 'going big' has brought added scrutiny to the subject of MPAs. There is economy in scale, but several people have called into question whether going large will protect representative habitat and result in true protection, or whether it is merely a politically expedient way for some nations to attain targets by creating paper parks, while avoiding tough conservation decisions.

3. The recent creation of large MPAs has greatly enhanced the chance of achieving global protection targets. Large areas typically contain several ecosystems and habitats that interact ecologically, and allow for more holistic conservation. The interactions between ecosystems in large MPAs occur without many of the problems associated with networks of smaller MPAs, where the connectivity between sites is often affected by human activities.

4. The disadvantages of large MPAs include difficulties of surveillance, enforcement and monitoring of vast offshore areas, as well as high total costs. While the cost per unit area may be lower for large MPAs, conducting surveillance and monitoring in such vast areas requires much more expensive technologies.

5. Large MPAs complement and add to existing management and conservation measures. Decision makers should consider designating them as one of a suite of possible protection measures. Besides greatly enhancing the chance of reaching agreed biodiversity targets, large MPAs improve the quality of conservation.

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INTRODUCTION

In recognition of the global crisis of dwindling biodiversity and increasing extinctions, the Convention on Biological Diversity (CBD) was opened for signatures at the United Nations Conference on Environment and Development (the Rio 'Earth Summit') in 1992 (CBD Secretariat, 2005). A second 'Earth Summit' was held in 2012, two years after the Conference of Parties no. 10 produced the 20 Aichi Biodiversity Targets (Anon., 2010). This is a broad set of initiatives which includes the goal of protecting at least 10% of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, by 2020. Although scientists and conservationists recognized that placing 10% of the global ocean under protection would not be sufficient to maintain biodiversity and stave off extinctions, the target was considered by many to be overly ambitious and politically unattainable. At the time, less than 1% of marine habitats were contained within MPAs (Spalding *et al.*, 2010) with the vast majority focused on nearshore and shallow-water habitats (Toonen *et al.*, 2013).

THE HISTORY OF GOING BIG

The last decade has seen a global trend toward the establishment of very large MPAs, which have been loosely defined as marine conservation areas that are approximately 250 000 km^2 in size or bigger (Toonen *et al.*, 2013).

This process began in 2000, when the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve, now known as the Papahānaumokuākea Marine National Monument and World Heritage site, was formed. Since then, there has been an increasing desire by some countries having large exclusive economic zones (EEZ) to consider similar protected areas within their national jurisdictions. Between 2000 and 2012, five large MPAs were established, all but one in the Pacific Ocean (Table 1; Figure 1). In addition, several other sizable MPAs are in the process of being established or are being proposed by governments and NGOs (Wood *et al.*, 2008; Leenhardt *et al.*, 2013). Most of these areas are located in remote places with low human populations, where protection is less contentious. These areas contain some of the most intact and least impacted ecosystems left on the planet (Halpern *et al.*, 2008).

The seven pioneer large MPAs (Table 1; Figure 1) now account for over 80% of the total area contained within MPAs (Toonen *et al.*, 2013). In these terms alone they are clearly important, and indeed the habitats enclosed within them are of key importance as well (Toonen *et al.*, 2013). The drivers toward protection of these recently designated MPAs are varied. Early large-scale sites, such as the Papahānaumokuākea Marine National Monument, were designated for their intrinsic natural and cultural value (Wiener and Wagner, 2013), while others like the Cook Islands Marine Park (Marae Moana) have multiple use zones and were established to strike a balance between economic growth and biodiversity conservation. Australia's Great Barrier Reef Marine Park, which has been a World Heritage Site since 1981, likewise has multiple use zones and a substantial management system (Fernandes *et al.*, 2005), while the British Indian Ocean Territory (BIOT) Marine Reserve is strictly no-take, off-limits to most, and has origins in its military functions (Sheppard *et al.*, 2012). Increasingly, however, ocean conservation advocates seek to establish new MPAs specifically to increase the proportion of the ocean set aside for protection (Cressey, 2011).

THE ADVANTAGES OF LARGE MPAs

Historically, protected areas have been designed for endangered species protection, fishery enhancement, or to regulate user conflicts and resource extraction (Fox *et al.*, 2012). With large and remote MPAs, the scope is expanded as they include diverse habitats and species assemblages that do not yet show signs of extraction pressures, and thus remain in very good ecological condition (Halpern *et al.*, 2008). In contrast, many small and coastal MPAs are located in areas with long histories of human uses from tourism to fishing, and therefore their regulations have needed to incorporate these pre-existing activities. Some large MPAs allow for

Table 1. Pioneer large-scale MPA sites (adapted from Toonen *et al.*, 2013)

Name	Country	Year founded	Size (km^2)	Proportion of site that is no-take (%)
Great Barrier Reef Marine Park	Australia	1975	344 000	33
Papahānaumokuākea Marine National Monument	USA	2000	362 074	100
Phoenix Islands Protected Area	Republic of Kiribati	2008	408 250	4
Mariana Trench Marine National Monument	USA	2009	246 609	100
British Indian Ocean Territory Marine Reserve	United Kingdom	2010	640 000	100
Motu Motiru Hiva Marine Park	Chile	2010	150 000 (with possible expansion to 411 000)	100
Cook Islands Marine Park	Cook Islands	2012	1 065 000	TBD

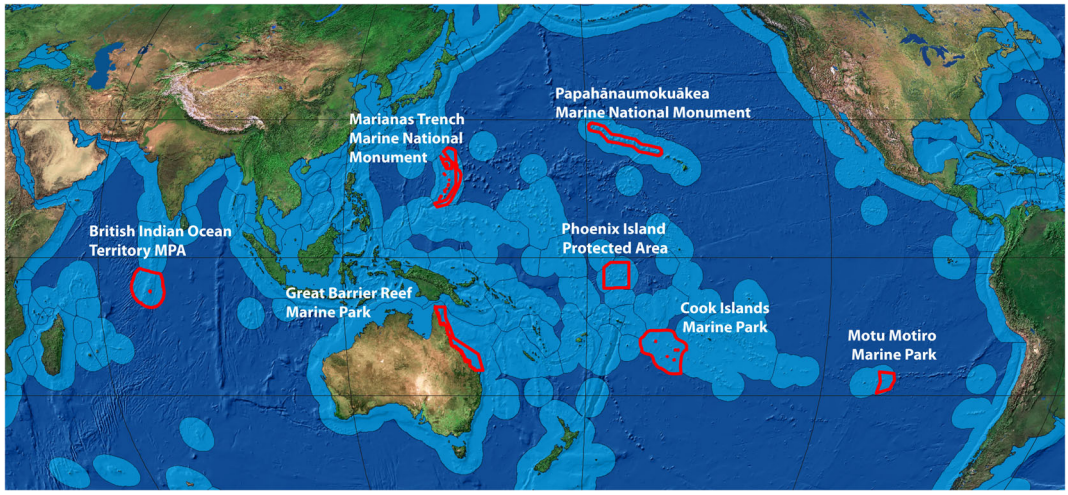

Figure 1. Map showing the location of the seven pioneer large-scale MPAs (adapted from Toonen *et al.*, 2013).

commercial fishing and other human uses in particular areas, often by necessity, though some are completely no-take (Table 1).

There has been an increase in scientific effort directed toward analysis of the costs and benefits of large MPAs (McCrea-Strub *et al.*, 2011; Toonen *et al.*, 2013; Edgar *et al.*, 2014). They offer a number of clear benefits, primarily the ability to protect whole ecosystems and interdependent habitats, so that biologically connected ecosystems can be included within the same management area. Given their vast size, large MPAs contain open ocean and deep-sea habitats, including seamounts, abyssal plains and trenches, that are usually not found in small MPAs (Toonen *et al.*, 2013). Many large MPAs encompass significant portions of the range of large and highly migratory species, such as tuna and marine mammals, thereby providing such species with protection measures not afforded by smaller MPAs. Furthermore, large areas are also more able to resist large-scale disturbances, and thus offer greater protection to the habitats they contain.

Many large MPAs extend to the limits of a country's entire EEZ. Thus some necessarily engage national governments, as well as those local agencies whose remit lies in ocean conservation. This may sometimes lead to unexpected legal and policy gains and shifts in public opinion that are unlikely to occur within smaller or more traditional MPAs. In terms of economic benefits, large MPAs may sometimes cost less per unit area to both implement and maintain, given economies of scale (McCrea-Strub *et al.*, 2011). Surveillance of large MPAs requires advanced technologies, such as satellites, aircrafts or large ships, all of which entail costs that rise rapidly with increased area and distance from shore, thus negating the concept of economy of scale in some cases. The total cost of establishing

large MPAs is generally higher than smaller ones, though as size increases establishment cost per unit area drops substantially (McCrea-Strub *et al.*, 2011).

Large MPAs provide unique opportunities to protect cultural seascapes and long practised oceanic traditions (Wiener and Wagner, 2013; Gaymer *et al.*, 2014). Large MPAs need not be uniform in use or management type. For instance, Australia's Great Barrier Reef Marine Park consists of a mosaic of zoned areas, some of which are strictly protected while others allow for certain extractive uses (Fernandes *et al.*, 2005). Such a mixed approach provides indigenous groups with unique opportunities to conduct traditional practices which otherwise may not survive.

WHERE LARGE MPAs ARE INEFFECTIVE OR HAVE DISADVANTAGES

The benefits of large-scale MPAs come with unique challenges. Impacts such as climate change and marine debris are global in nature, thus affecting large MPAs as much as any other areas. In some cases, the remote location of many large-scale MPAs intensifies the problem. For instance, the BIOT Marine Reserve which is located downcurrent from South-east Asia (Figure 1), receives much litter and degraded microplastics generated upcurrent of the reserve (Readman *et al.*, 2013). Similarly, oceanic circulation patterns deposit significant amounts of marine debris in the Papahānaumokuākea Marine National Monument from the North Pacific (Donohue, 2003), and this is also the case for the Motu Motiro Hiva Marine Park, which is located in the centre of the South Pacific Subtropical Gyre (Figure 1), where debris and microplastics from all around the South Pacific rim accumulate (Hidalgo-Ruz and Thiel, 2013). Several large MPAs have also faced significant political and economic objections from powerful lobbies such as the industrial fishing interests, due to the inherent value of the resources that may no longer be extracted.

As a result of the greater overall cost of surveillance and management in large MPAs, coordination between different agencies becomes a necessity, which in turn can add additional obstacles. One of the most prevalent criticisms of large-scale MPAs is that they are difficult to enforce. However, this is a criticism not of the concept of large MPAs themselves, but rather of the lack of resources available to enforce or manage them. In particular, some extractive industries have argued that if the full potential of a large MPA cannot be achieved, then it should not be implemented at all; clearly a self-serving statement. Industrial fishing interests are notably critical of the effectiveness of large MPAs (see Kaplan *et al.*, 2013; Pala, 2013). A common criticism from industrial fishing interests is that large MPAs will not reduce overall catch, but merely displace fishing efforts elsewhere (Kaplan *et al.*, 2013). However, even with highly migratory tuna, as much as 50% of the tuna may not leave a suitably sized protected area, thereby reducing the amount of tuna originating from the MPA that can be caught outside the MPA boundary (Sibert and Hampton, 2003).

Several of the existing large MPAs have particularly high fish biomasses, which make them attractive to illegal, unreported and unregulated (IUU) fishing activities. This heightens the need for effective surveillance and enforcement. However, surveillance and enforcement are a challenge in large MPAs, as they require advanced technological capabilities which are costly. The difficulty for the MPA or fisheries managers is similar whether the large MPA is no-take or has fishing zones. In the latter case, there is the challenge of keeping IUU fleets outside the no-take boundaries and ensuring that licensed ships comply with catch quotas. This may be particularly difficult to enforce, because licensed fishing vessels may land their catches a long distance from where the fish were caught, a feature of much less concern to fishing efforts in coastal and small MPAs.

Large MPAs, like any others, may have less effect than expected if placement design is mainly residual, that is, located in areas that have little commercial interest anyway. In Australia, Devilliers *et al.* (2014) found that the country's new system of protected areas was chosen with an aim of minimizing conflict with various stakeholders. While such avoidance is a sensible motive, they found that the extent to which this

was planned in parts of Australia was surprisingly high, and gave a false and unjustified sense of progress in conservation. In some cases MPA designations have not been preceded by sufficient consultation with affected human populations (Gaymer *et al.*, 2014). While this applies to any sized MPA, it may be more difficult for large sites because of the increase in overall issues and their complexity. Others have argued that just as fishery management decisions are made at national and regional levels, MPA management decisions should be made similarly, ensuring broad participation beyond local communities (Leenhardt *et al.*, 2013). However, managing places that are far away from human population centres can also pose significant challenges to sustained community engagement, governmental support and necessary resource allocation.

THE WAY AHEAD FOR LARGE MPAs

While there are many challenges and criticisms of large-scale MPAs, if properly designed and managed, they can meet the primary objectives of all of IUCN's protected area categories (Dudley, 2013). Owing to their large size, and even with only passive management, these sites all have the potential to protect natural biodiversity and environmental processes (category II), as well as protect specific outstanding natural features and their associated biodiversity and habitats (category III). With active management, these sites can also maintain, conserve and restore species and habitats (category IV), thereby helping to reduce or arrest declines in biodiversity and productivity. In the Pacific, several large MPAs already protect and maintain important seascapes and other values created by human interactions through traditional management practices (category V).

Cultural heritage is not always an obvious objective of countries that have or seek to establish large MPAs, especially when they are a great distance from human population centres. Some countries have designated large areas to protect natural ecosystems for sustainable use (category VI), using a variety of planning approaches (e.g. marine zoning, marine spatial planning, culture-based approaches). By doing so, they provide the opportunity for mixed uses, including cultural practices. Developing nations, in particular small island states, have fewer economic resources and rely heavily on income from their EEZs. In these cases, fully no-take areas are not possible, thus requiring different use zoning.

Large MPAs require a mix of management tools and approaches, because large areas inherently contain multiple habitats, ecological processes and interdependencies (Leenhardt *et al.*, 2013; Toonen *et al.*, 2013). It is important for those who are considering the establishment of large-scale MPAs to weigh all the potential drawbacks against the benefits, and learn from the large MPAs that have already been established (Table 1). To assist this, a handbook on the *Design and Management of Large-Scale MPAs* is currently being developed (Big Ocean and WCPA-Marine, 2014). Whatever the nature of a large MPA (i.e. no-take or zoned for multiple uses), it is important to avoid becoming a 'paper park' that offers no protection beyond the initial government declaration. While the declaration of MPAs is a start, effective management is required in order to achieve the Aichi Bodiversity Target 11.

Large MPAs are not a panacea; they should be considered as only one of several available conservation tools, including marine spatial planning, single species management, fisheries measures, zoning schemes and smaller coastal MPAs. They will not be the best approach in all cases or for all places, and should not be viewed as the most cost-effective, efficient or convenient way to achieve global ocean conservation targets. Large-scale MPAs are difficult in several respects, but due to the decline of the world oceans, initiatives of increased size, scope and scale are needed. The effective management of the ocean will require a mix of management tools, and large MPAs add features that cannot be addressed by other management measures. They should work in concert with other conservation approaches at an archipelagic, coastal or regional scale as appropriate and possible. Several large MPAs are currently being promoted based on their importance to global biodiversity and their ability to protect whole ecosystems, particularly in areas where the local political will that is necessary to

engage in the long-term surveillance and full implementation of the MPA is present (Nelson and Bradner, 2010; Friedlander *et al.*, 2013). Ideally they should be placed where gains in conservation can be measured over time, and where management can be established and enhanced as needed.

Increases in fish stocks are often used as indicators of whether an MPA is working (Russ and Alcala, 1996; Miller *et al.*, 2012). However, large MPAs in pristine areas may already have high fish stocks, and in such cases further stock improvements may simply not be likely, so keeping the stock at the same high level may be all that is possible. In other cases, where MPAs were designed for other purposes (e.g. recover fish stocks), stock improvements may of course still be sensible. There is a need to reverse the burden of proof here, and challenge the extractive industry to prove it can exploit without causing significant damage. Commonly, a simple ability to maintain present conditions would certainly be a major achievement in oceans where many habitats are in general decline (Gardner *et al.*, 2003; Bruno and Selig, 2007). One measurement proposed in this context, is measuring the increasing difference between the MPA and adjacent ocean regions that are being exploited.

Coral reefs are one of the most threatened habitats, and are the focus of several large MPAs. Reefs have been considered to provide 99 benefits to humankind in nine major categories (Angulo-Valdés and Hatcher, 2010), including monetary and non-commercial ones. One calculation shows that even by omitting tourism and fishing, the BIOT Marine Reserve provides a monetary equivalent of over $ US 8 billion per year to the greater region (Gravestock and Sheppard, manuscript in preparation). Similar analyses show an equally great value for the Great Barrier Reef (Deloitte, 2013). Such valuations are a beneficial exercise for all large MPAs. While many interconnected habitats, including reefs, mangroves, seagrasses and others, will undoubtedly suffer damage from climate change (Veron *et al.*, 2009), protection from locally preventable impacts will greatly prolong the values that they presently give (Selig and Bruno, 2010; Kennedy *et al.*, 2013).

Our ultimate dependence on natural resources is non-negotiable and more valuable that the total global economy (Costanza *et al.*, 2014), so functioning ecosystems should not be viewed as a mere stakeholder interest like fishing or tourism. Large MPAs should become a key element of the total suite of measures available to ensure optimal functioning. Much of the world will continue to be heavily exploited, but some areas need to be left intact for strong and valid scientific reasons, and for reasons that support humankind. In the future, present difficulties in funding and conflicting interests will possibly be viewed in the manner that we may now regard the comments made by the first US official to visit the Grand Canyon, today an icon of terrestrial reserves: 'The region is, of course, altogether valueless. It can be approached only from the south, and after entering it there is nothing to do but leave. Ours has been the first, and will doubtless be the last, party of whites to visit this profitless region' (Ives, 1861).

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REFERENCES

Angulo-Valdés J, Hatcher BG. 2010. A new typology of benefits derived from marine protected areas. *Marine Policy* **34**: 635–644.

Anon. 2010. Decisions adopted by the Conference of the parties to the Convention on Biological Diversity at its Tenth Meeting X/2 Strategic Plan for Biodiversity 2011–2020: UNEP/CBD/COP/DEC/X/2.

Big Ocean, WCPA-Marine. 2014. Guidelines for the Design and Management of Large-scale Marine Protected Areas. *IUCN World Commission on Protected Areas.* IUCN: Gland, Switzerland.

Bruno JF, Selig ER. 2007. Regional decline of coral cover in the Indo-Pacific: timing, extent, and subregional comparisons. *PLoS One* **2**: e711.

CBD Secretariat. 2005. *Handbook of the Convention on Biological Diversity Including its Cartagena Protocol on Biosafety*, 3rd edn. UNEP/CBD: Montreal, Canada.

Costanza R, de Groot R, Sutton P, van der Ploeg S, Anderson SJ, Kubiszewski I, Farber S, Turner RK. 2014. Changes in

the global value of ecosystem services. *Global Environmental Change* **26**: 152–158.
Cressey D. 2011. Uncertain sanctuary. *Nature* **480**: 166–167.
Deloitte Access Economics. 2013. Economic contribution of the Great Barrier Reef, Great Barrier Reef Marine Park Authority, Townsville.
Devilliers R, Pressey RL, Grech A, Kittinger JN, Edgar GJ, Ward T, Watson R. 2014. Reinventing residual reserves in the sea: are we favouring ease of establishment over need for protection? *Aquatic Conservation: Marine and Freshwater Ecosystems*. DOI: 10.1002/aqc.2445/abstract
Donohue MJ. 2003. How multiagency partnerships can successfully address large-scale pollution problems: a Hawaii case study. *Marine Pollution Bulletin* **46**: 700–702.
Dudley N. 2013. Guidelines for applying protected area management categories - developing capacity for a protected planet. Best practice protected area guidelines series No. 21 IUCN/WCPA, CBD, Fundación Biodiversidad, Junta de Andalucía, Korea National Park.
Edgar GJ, Stuart-Smith RD, Willis TJ, Kininmonth S, Baker SC, Banks S, Barrett NS, Becerro MA, Bernard ATF, Berkhout J, *et al*. 2014. Global conservation outcomes depend on marine protected areas with five key features. *Nature* **506**: 216–220.
Fernandes L, Day J, Lewis A, Slegers S, Kerrigan B, Breen D, Cameron D, Jago B, Hall J, Lowe D, *et al*. 2005. Establishing representative no-take areas in the great barrier reef: large-scale implementation of theory on marine protected areas. *Conservation Biology* **19**: 1733–1744.
Fox HE, Solanoff CS, Mascia MB, Haisfield KM, Lombana AV, Pyke CR, Wood L. 2012. Explaining global patterns and trends in marine protected area (MPA) development. *Marine Policy* **36**: 1131–1138.
Friedlander AM, Ballesteros E, Beets J, Berkenpas E, Gaymer CF, Gorny M, Sala E. 2013. Effects of isolation and fishing on the marine ecosystems of Easter and Salas y Gómez islands, Chile. *Aquatic Conservation: Marine Freshwater Ecosystems* **23**: 515–531.
Gardner TA, Cote IM, Gill JA, Grant A, Watkinson AR. 2003. Long-term region-wide declines in Caribbean corals. *Science* **301**: 958–960.
Gaymer CF, Stadel AV, Ban NC, Carcamo F, Ierna J Jr., Lieberknecht LM. 2014. Merging top-down and bottom-up approaches in marine protected areas planning: experiences from around the globe. *Aquatic Conservation: Marine and Freshwater Ecosystems* (this issue)
Halpern BS, Walbridge S, Selkoe KA, Kappel CV, Micheli F, D'Agrosa C, Bruno JF, Casey KS, Ebert C, Fox HE, *et al*. 2008. A global map of human impact on marine ecosystems. *Science* **319**: 948–952.
Hidalgo-Ruz V, Thiel M. 2013. Distribution and abundance of small plastic debris on beaches in the SE Pacific (Chile): a study supported by a citizen science project. *Marine Environmental Research* **87**: 12–18.
Ives JC. 1861. Report upon the Colorado river of the west: explored in 1857 and 1858. Government Printing Office, Washington, DC.
Kaplan D, Bach P, Bonhommeau S, Chassot E, Chavance P, Dagorn L, Davies T, Dueri S, Fletcher R, Fonteneau A, *et al*. 2013. The true challenge of giant marine reserves – response. *Science* **340**: 810–811.
Kennedy EV, Perry CT, Halloran PR, Iglesias-Prieto R, Schönberg CHL, Wisshak M, Form AU, Carricart-Ganivet JP, Fine M, Eakin M, *et al*. 2013. Avoiding coral reef functional collapse requires local and global action. *Current Biology* **23**: 912–918.
Leenhardt P, Cazalet B Salvat B, Claudet J, Feral F. 2013. The rise of large-scale marine protected areas: conservation or geopolitics? *Ocean and Coastal Management* **85**: 112–118.
McCrea-Strub A, Dirk Zeller D, Sumaila UR, Nelson J, Balmford A, Pauly D. 2011. Understanding the cost of establishing marine protected areas. *Marine Policy* **35**: 1–9.
Miller I, Cheal AJ, Emslie MJ, Logan M, Sweatman H. 2012. Ongoing effects of no-take marine reserves on commercially exploited coral trout populations on the Great Barrier Reef. *Marine Environmental Research* **79**: 167–170.
Nelson J, Bradner H. 2010. The case for establishing ecosystem-scale marine reserves. *Marine Pollution Bulletin* **60**: 635–637.
Pala C. 2013. Giant marine reserves pose vast challenges. *Science* **339**: 640–641.
Readman JW, DeLuna F, Ebinghaus R, Guzman A, Price ARG, Readman EE, Sheppard ALS, Sleight VA, Sturm R, Thompson RC, *et al*. 2013. Contaminants, pollution and potential anthropogenic impacts in Chagos/BIOT. In *Coral Reefs of the United Kingdom Overseas Territories*, Sheppard CRC (ed.). Springer: Dordrecht, Netherlands; 283–298.
Russ GR, Alcala AC. 1996. Do marine reserves export adult fish biomass? Evidence from Apo Island, central Philippines. *Marine Ecology Program Series* **132**: 1–9.
Selig ER, Bruno JF. 2010. A global analysis of the effectiveness of marine protected areas in preventing coral loss. *PLoS One* **5**: e9278.
Sheppard CRC, Ateweberhan M, Bowen BW, Carr P, Chen CA, Clubbe C, Craig MT, Ebinghaus R, Eble J, Fitzsimmons N, *et al*. 2012. Reefs and islands of the Chagos Archipelago, Indian Ocean: why it is the world's largest marine protected area. *Aquatic Conservation: Marine and Freshwater Ecosystems* **22**: 232–261.
Sibert J, Hampton J. 2003. Mobility of tropical tunas and the implications for fisheries management. *Marine Policy* **27**: 87–95.
Spalding M, Wood L, Fitzgerald C, Gjerde K. 2010. The 10% target: where do we stand? In *Global Ocean Protection: Present Status and Future Possibilities*, Toropova C, Meliane I, Laffoley D, Matthews E, Spalding M (eds). Agence des Aires Marines Protégées: Brest, France, Gland, Switzerland, Washington, DC and New York, USA: IUCN WCPA, Cambridge, UK: UNEP-WCMC, Arlington, USA: TNC, Tokyo, Japan: UNU, New York, USA: WCS; 25–40.
Toonen RJ, Wilhelm TA, Maxwell SM, Wagner D, Bowen BW, Sheppard CRC, Taei SM, Teroroko T, Moffitt R, Gaymer CF, *et al*. 2013. One size does not fit all: the emerging frontier in large-scale marine conservation. *Marine Pollution Bulletin* **77**: 7–10.
Veron JEN, Hoegh-Guldberg O, Lenton TM, Lough JM, Obura DO, Pearce-Kelly P, Sheppard CRC, Spalding M, Stafford-Smith MG, Rogers AD. 2009. The coral reef crisis: the critical importance of < 350 ppm CO_2. *Marine Pollution Bulletin* **58**: 1428–1436.
Wiener CS, Wagner D. 2013. Sailing through time: a historical examination of the explorations and investigations of the Papahānaumokuākea Marine National Monument. *Atoll Research Bulletin* **594**: 1–23.
Wood LJ, Fish L, Laughren J, Pauly D. 2008. Assessing progress towards global marine protection targets: shortfalls in information and action. *Oryx* **42**: 340–351.