Quantitative targets for marine protection: a review of the scientific basis and applications

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Summary

Marine protected areas (MPAs) are an effective conservation tool to halt the global loss of marine species as anthropogenic threats to biodiversity increasingly affect the oceans. Recognizing the conservation benefits of MPAs, international agreements call for nations to establish effective MPA networks with the goal of conserving marine ecosystems. For example, the Convention on Biological Diversity (CBD), which New Zealand is a party to, prescribed a set of 20 conservation targets (Aichi Targets) to be met by 2020, as part of the Strategic Plan for Biodiversity 2011–2020. These targets included protecting 10% of coastal and marine areas within MPAs and other effective area-based conservation measures (Aichi Target 11). However, international coverage targets like Aichi 11 have been criticised because they are based on limited scientific evidence and may promote the importance of MPA spatial coverage rather than their effectiveness (e.g., the level of protection they afford). Despite this, coverage targets are popular among policymakers, because they are easy to quantify and because progress in meeting spatial targets can be easily assessed.

The year 2020 marks the end of the CBD's Strategic Plan for Biodiversity 2011 – 2020, and international organisations and individual countries are working to define post-2020 targets for the conservation of nature. Therefore, there is increased international impetus to identify effective targets for marine protection with an evidence-based approach. Additionally, New Zealand is undertaking a reform of its domestic MPA legislation, which affords the opportunity to develop science-based targets for marine protection within New Zealand.

Here we review: (1) the methods used internationally to identify science-based coverage targets for protection of coastal and marine areas; (2) the values of MPA coverage required to meet conservation objectives; (3) the main shortcomings of coverage targets; (4) the coverage targets that have guided marine protection policies in New Zealand and other countries with comparable ecological and socioeconomic settings (Australia, Canada, United Kingdom, and United States); and (5) the progress towards meeting coverage targets in these countries.

Internationally, the effectiveness of quantitative targets for conservation has been evaluated using a variety of different approaches, including species-area curves, numerical modelling of minimum thresholds of protection, systematic conservation

planning, and heuristic principles. Of these, systematic conservation planning, a spatially-explicit modelling technique that evaluates whether MPA networks meet conservation objectives, has been used most extensively to evaluate and revisit coverage targets.

Previous literature has indicated that >30% MPA coverage (and up to 50% according to some studies) will be necessary to protect biodiversity and support human activities in marine areas. To update previously published reviews, we reviewed recent studies (2016 – 2020) that identified MPA coverage targets required to meet a number of objectives, including to protect biodiversity, to ensure connectivity, to benefit fisheries, and to avoid stock collapses. Importantly, we found that values for effective coverage targets depend on the conservation objectives to be achieved, and on the ecological features of the areas to protect. For example, where biodiversity protection was the primary objective of MPAs, required MPA coverage ranged between 13% and 90% (median 34%) depending on the biodiversity features to be protected, whereas when the objective was to preserve or enhance fisheries value, required MPA coverage ranged between 20 and 50% (median 25%) depending on other fishery management measures. This highlights the importance of setting explicit objectives for MPAs, and identifying conservation targets that allow those objectives to be met.

We also reviewed the coverage targets that have guided MPA planning in New Zealand, Australia, Canada, the United Kingdom and the United States, all of which have been assessing their progress towards meeting Aichi Target 11 (including the United States, which is not a party to the CBD). Although these countries have reported in international forums (including reports to the CBD) that they have met the quantitative area-based 10% component of Aichi Target 11, the qualitative principles of Aichi Target 11, such as “representativeness” and “effective management” of MPA networks, have not always been applied successfully. It is therefore important to guard against an over-emphasis on quantitative conservation targets at the expense of qualitative targets related to the effectiveness of conservation measures.

Post-2020 targets in New Zealand will need to address the loss of biodiversity and the effects of climate change on ecosystems. Extensive scientific evidence shows that 10% MPA coverage is almost always insufficient to meet conservation goals. However, optimal MPA coverage depends on the conservation objectives at hand, and the application of universal coverage targets to all conservation problems indistinctively is discouraged. Data-driven systematic conservation planning is a useful, scientifically valid approach that may be used in New Zealand to set effective targets for marine protection in the future. This will require data from ecological monitoring programs, and may also be used for future periodic revision of the effectiveness of conservation targets over time. Future conservation targets should also specify qualitative principles for MPA planning, including representing all habitats, supporting biologically viable populations, and being well-connected, to ensure that MPA networks will be effective in conserving marine ecosystems. Finally, effective management will also be important to deliver the conservation objectives pursued by future targets in New Zealand.

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1. Introduction

The oceans provide humanity with essential food security and protection from climate change. There are many pressures that have contributed to, and continue to contribute to a steady global loss of marine species, habitats, ecosystem services for human use, and ecological functions of marine ecosystems (e.g. Worm et al. 2006, McCauley et al. 2015). These include global climate change, population increase, industrialisation, pollution, exploitation of mineral resources, and fishing. The depletion and biological degradation of the oceans resources has motivated global efforts towards marine protection over the last few decades. The establishment of Marine Protected Areas (MPAs) is one of the most effective conservation measures to have been adopted globally.

International agreements have been reached to coordinate global efforts towards the conservation of nature. The Convention of Biological Diversity (CBD) is a multilateral, international treaty that was signed in 1992 in Rio De Janeiro, with the goal of guiding nations towards the protection of nature and its sustainable use. As a party to the CBD, New Zealand is committed to meeting its objectives. To provide a framework for the achievement of CBD objectives, the parties to the CBD adopted in 2010 the Strategic Plan for Biodiversity (SPB) 2011 – 2020 at the 10th CBD meeting in Nagoya, Japan. The SPB includes 20 Targets (the Aichi Targets) that the parties were to strive to achieve by 2020. One of these targets, Aichi Target 11, called for the commitment of all parties to the CBD to conserve 10% of coastal and marine areas by 2020. Specifically, Aichi Target 11 prescribes that "*By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes*".

Quantitative targets that call for percentage area to be protected, such as that included in Aichi Target 11, are often referred to as coverage or area-based targets. Coverage targets for MPA networks have been widely adopted internationally to pursue conservation goals, largely because aiming to protect a certain percentage of a country's coastal and marine areas is easy to quantify and understand (Wood 2011).

Aichi Target 11, however, also contains qualitative attributes of protected area networks, including "*equitably managed*", "*ecologically representative*", "*well-connected*", and "*integrated into the wider landscape and seascape*". These qualitative elements of coverage targets are important, and they guide the development protection frameworks that are oriented towards effectively protecting biodiversity (Rees et al. 2018).

Aichi Target 11 is not the only international coverage target for MPA networks. In 2015, members of the United Nations General Assembly adopted a set of Sustainable Development Goals (SDGs), to guide global development strategies that preserve nature and reduce poverty over the 2015 – 2030 period. SDG 14.5[1] reiterated the 10% coverage target for marine and coastal areas of Aichi Target 11, but did not include the qualitative properties of the CBD target (Rees et al. 2018).

Over the last decade, the international scientific community has expressed the concern that the 10% target is inadequate to meet conservation objectives. In the 2014 World Parks Congress held in Sydney, Australia, the International Union for the Conservation of Nature (IUCN) acknowledged that "*many delegates argued that these* [percentage area targets] *should be around at least 30 per cent of the planet for no-take reserves, 50 per cent overall protection, and 100 per cent of the land and water managed sustainably*". Following up to the "Promise of Sydney", the IUCN released Resolution WCC-2016-Res-050 (IUCN 2016) that encouraged nations to protect at least 30% of each marine habitat by 2030.

Coverage targets have the advantage of being easy to understand and quantify, which aids the often largely political process of planning and implementing protection (Tear et al. 2005, Wood 2011, Green et al. 2019). Therefore, many conservation scientists believe that coverage targets are an important tool for nature conservation (Woodley et al. 2019a). However, international coverage targets have also been the focus of much criticism from the scientific community (e.g. Carwardine et al. 2009, Agardy et al. 2016). Such criticism included: lacking scientific validity (Carwardine et al. 2009); being unclear in their formulation and in defining which habitat types, geographic regions, or natural features should be protected (Agardy et al. 2003, Visconti et al.

[1] SDG 14.5 By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information.

2019); and in general being consistently too low (e.g. Rodrigues and Gaston 2001, Woodley et al. 2019a). Some authors are particularly critical towards coverage targets like Aichi Target 11, seeing them as a missed opportunity to achieve effective conservation of nature, or even as responsible for perverse outcomes for conservation (Agardy et al. 2003, Visconti et al. 2019). Perverse outcomes of coverage targets include the establishment of MPAs in areas that are residual to human use instead of areas that are in need of protection, in order to meet coverage targets while avoiding socio-economic conflict (Devillers et al. 2015). Recognizing some of these criticisms, coverage targets greater than 10% have been proposed by scientists for protecting coastal and marine areas, and it is frequent to see in the scientific literature figures of 20–40%, and as much as 50% (Wilson 2016, Woodley et al. 2019b). Even though high targets may be considered socially unacceptable and politically unviable (Carwardine et al. 2009), some authors have defended high targets for conservation if these are based on the scientific understanding of the ecosystems to protect (Locke 2013).

As we approach the end of the Strategic Plan for Biodiversity 2011 – 2020, the progress towards meeting international targets for protection is being evaluated, and post-2020 targets must be defined (Mace et al. 2018, Visconti et al. 2019, Woodley et al. 2020). There is ongoing discussion around the targets to be used to guide the next phase of conservation of nature, and the overlap between the goal of protecting nature and the goal of mitigating the impact of climate change is increasingly recognised (Roberts et al. 2017, 2020, Dinerstein et al. 2019). Some conservation scientists have also highlighted the need of outcome-based targets built on appropriate biodiversity indicators (Visconti et al. 2019), although coverage targets will likely retain an important role (Woodley et al. 2020).

2. Objectives of this report

Recognizing that coverage targets are likely to retain an important role in marine policy, it is important to identify the scientific basis that justifies the values of MPA percentage coverage pursued at national and international levels. A growing body of literature has investigated the minimum effective coverage targets for protection of coastal and marine areas, using a number of scientific methods. In this report, we review the main methods used by scientists to identify appropriate MPA coverage targets for achieving conservation objectives, the values of minimum coverage that have been proposed in the scientific literature to meet conservation objectives, and the application of coverage targets in New Zealand and other developed countries with similar ecological and socioeconomic settings. The specific objectives of this report were to review:

1. The scientific methods for establishing coverage targets for the protection of coastal and marine areas (referred to as marine protection hereafter, noting that it also encompasses estuaries).
2. The evidence-based values of minimum MPA coverage required to meet conservation objectives.
3. The most common shortfalls and criticisms of coverage targets.
4. The coverage targets that have guided marine conservation in New Zealand and in other countries with ecological and socioeconomic settings comparable to New Zealand (Australia, Canada, United Kingdom, and United States), and examples of the scientific processes that have been used at national levels to support or revisit these targets.
5. The progress towards meeting coverage targets in these countries, as their governments have reported in international forums.

3. Scientific methods for establishing coverage targets

To protect biodiversity, MPAs often prohibit, to variable extent, extractive activities like fishing and mining. Therefore, marine protection can displace existing human activities, and may be met with opposition from some stakeholders (Fitzsimons and Wescott 2018). Thus, MPA planning is often in part driven by political and socioeconomic forces. However, it is important to include objective scientific information in the process of establishing conservation targets, including coverage targets, or the actual progress towards conservation objectives will be hampered by political discussion (Noss et al. 2012). Legal frameworks for MPA planning of many countries call for the use of the best available scientific evidence. For this reason, scientific evaluations of the effectiveness and appropriateness of coverage targets have been popular.

We searched Elsevier’s online database Scopus (www.scopus.com) for peer-reviewed literature on science-based quantitative targets for marine protection. We searched the titles, abstracts and keywords of the listed records for the words “conservation targets”, “conservation objectives”, and “marine protected area targets”. This last keyword restricted our search to studies focusing on marine areas (or both marine and terrestrial), and if the searches still returned studies examining only terrestrial protected areas, these studies were not considered further. The topic of scientific basis for conservation targets has received previous attention, and a systematic literature review of the topic would have overlapped with existing comprehensive reviews. To restrict the pool of articles to examine, we focused on review papers on the scientific evidence for coverage conservation targets. To identify additional relevant review papers, as well as key studies presented in such reviews (e.g. articles introducing or discussing a specific method to set coverage targets), we then used Scopus to search articles cited by (and citing) these review papers, in backwards and forwards searches that complemented the first Scopus search.

We found seven review papers presenting an overview of the scientific methods that have been used to inform or re-evaluate coverage targets: Roberts and Hawkins (2000), Svancara et al. (2005), Rondinini and Chiozza (2010), O’Leary et al. (2016), Nicholson et al. (2019), Woodley et al. (2019a, 2019b). Drawing from these seven reviews and from the original research cited within them, we identified four main methods to inform evidence-based coverage targets for protection: species-area curves, threshold analysis, systematic conservation planning, and heuristic principles.

3.1. Species-area curves

Species-area curves describe the relationship between an area and the number of species that the area supports (Rosenzweig 1995). In principle, larger areas can support more species (Gotelli and Colwell 2001). Woodley et al. (2019b) listed species-area curves as widely used method to estimate the extent of an area that needs to be protected in order to maintain a proportion of the species that it hosts. With this method, Wilson (2016) estimated that protecting 50% of the world’s landmass will ensure the persistence of 85% of the world’s terrestrial species.

Rondinini and Chiozza (2010) highlighted the difference between generic species-area curves parameterised with data from the literature for a given geographic area, and habitat-specific species-area curves, which account for different species accumulation rates between different habitat types. The latter is a more precise method of describing how many species a proportion of a habitat can host (and how many species will be lost as the habitat disappears), but it is more data-demanding. The use of species-area curves to identify the proportion of a habitat to protect is conceptually different from establishing global conservation goals (Woodley et al. 2019b).

Species-area curves can be a useful method for identifying coverage targets in data-limited contexts, because general species-area relationships have been described previously in ecological theory (MacArthur and Wilson 1967, Rosenzweig 1995). Moreover, because of the simplicity and repeatability of the approach, species-area curves can be easily communicated by scientists to stakeholders and managers (Rondinini and Chiozza 2010). However, defining coverage targets with species-area curves has limitations. First, the method aims to identify the proportion of a habitat required for species representation but not for its persistence, because species-area curves do not incorporate information on the ecological processes that are required for a species to maintain a viable population (Rondinini and Chiozza, 2010). Furthermore, even habitat-specific species-area curves may not capture the relationship between the species of interest and microhabitats (10s – 100s of m), which are an important determinant for species occurrence and persistence (Banks and Skilleter 2007). Finally, conservation targets set with species-area curves are highly sensitive to model formulation (Davis et al. 2017, Drira et al. 2019).

Woodley et al. (2019a) reported that around 20% of interviewed conservation scientists (n = 335) identified species-area curves as "*best approach to arrive at a % area of land or sea to protect*" (includes marine and terrestrial conservation indistinctively).

3.2. Threshold analysis

Threshold analyses identify a level of protection below which undesirable ecological effects take place (Svancara et al. 2005). Examples of such effects are stock collapses, species loss, and regime shifts. Woodley et al. (2019b) more specifically referred to the identification of thresholds of minimum ecosystem size, which is the threshold of protection needed to avoid a major, irreversible change in the ecosystem. A commonly used threshold analysis is spatially-explicit Population Viability Analysis (PVA, reviewed in Rondinini and Chiozza 2010), which is a species-specific modelling approach with the purpose of calculating which proportion of a habitat is necessary to support a viable population of a certain species. The focus of PVAs is often on “umbrella species”, that are considered representative of a large number of species in the ecosystem.

Some types of threshold analysis, like PVA, have the advantage that they aim to ensure the persistence of the modelled species, and not only their occurrence like species-area curves do (Rondinini and Chiozza 2010). In addition, some models used for threshold analysis include information on suitable habitat and not only on geographic extent (Svancara et al. 2005). However, PVA models are typically difficult to apply to more than one species at a time, and the use of “umbrella species” to represent the conservation requirements of other species can be an oversimplification (Rondinini 2010).

3.3. Systematic conservation planning

Systematic conservation planning is one of the most popular methods of planning protected area networks and testing the effectiveness of quantitative conservation targets (Svancara et al. 2005, Nicholson et al. 2019, Woodley et al. 2019), with over 40% of conservation scientists interviewed by Woodley et al. (2019a) identifying systematic conservation planning tools as an appropriate method to establish coverage targets (includes marine and terrestrial conservation indistinctively).

Systematic conservation planning uses spatially explicit analytical approaches to determine the optimal extent and location of protected areas to achieve conservation outcomes with respect to the protection of a set of ecological features (and optionally a set of human activities to account for when planning MPAs). In these studies, conservation outcomes are often expressed as the percentage of the extent of each ecological feature that is protected. Ecological features to be protected (or enhanced) by the MPA network may be biogeographic regions (Barr and Possingham 2013, Butchart et al. 2015, Jantke et al. 2018), areas important for biodiversity (Butchart et al. 2015, Gownaris et al. 2019), the area of occurrence of species of interest (Butchart et al. 2015, Klein et al. 2015, Davidson and Dulvy 2017), habitat types as predicted by habitat suitability models (Rowden et al. 2019), patterns of species movement and habitats use (Daly et al. 2018), geomorphic features (Fischer et al. 2019), rare habitats that require full protection (Sala et al. 2002), and commercial activities that are compatible with conservation objectives (Chollet et al. 2016).

Importantly, systematic conservation planning is most frequently used to determine if *a priori* coverage targets have been met, rather than to determine the coverage targets. For example, some studies have evaluated whether MPA networks successfully protect 10% (Butchart et al. 2015, Jantke et al. 2018) or 30% (Zhao et al. 2020) of marine ecoregions, ecosystem types, or habitats globally, where 10% and 30% are based on international coverage targets. Other studies have evaluated the performance of national MPA networks in protecting given percentages of specific habitats or species distributions, with such percentages obtained from previous scientific assessment (Timonet and Abecasis 2020) or other methods like species-area curves (Drira et al. 2019). After evaluating whether the existing MPA networks meet the conservation objectives, the method may be used to plan the expansion of the network, should this be inadequate.

Systematic conservation planning can also be used to quantify the percentage of a region to set aside for protection. For example, to achieve a predetermined objective of protecting 20% of each representative coastal habitat in the Gulf of California (and other conservation objectives) Sala et al. (2002) used systematic conservation planning tools to propose a network of MPAs that occupied ~40% of the rocky reef coastal habitats of the Gulf of California. .

Svancara et al. (2005) highlighted that MPA coverage requirements set with systematic conservation planning are highly variable, because they depend on the conservation objectives. For example, conservation objectives like the protection of a set of species may be met with relatively low coverage targets, depending on the identity of the focal species. Davidson and Dulvy (2017) evaluated the overlap between the global MPA network and the distribution of over 1000 species of chondrichthyans (sharks, rays etc.), 99 of which were imperilled. They showed that protecting 13% of the world's ice-free Exclusive Economic Zones (EEZs) would protect all 99 imperilled endemic species, and 78% of the imperilled non-endemic species. However, if the objective is to protect multiple habitats, ecoregions, and fishery interests, minimum required MPA coverage may be as high as 30–50% (Airamé et al. 2003).

Systematic conservation planning is a flexible method of identifying the shortcomings of MPA networks from regional to global scales (Nicholson et al. 2019, Woodley et al.

2019b). However, this method requires extensive spatially-resolved data of the features to protect, and of the human activities to consider in conservation planning. Marine habitat data is difficult to collect and is therefore often sparse, and biological data are often approximated with surrogates like geophysical data (e.g. Anderson et al. 2011, Przeslawski et al. 2011). Similarly, species distribution data is subject to uncertainty (Akçakaya et al. 2000), which should be accounted for in systematic conservation planning (Rowden et al. 2019).

3.4. Heuristic principles

One of the main hurdles to the establishment of science-based conservation targets is the sparsity of biological data (Pressey 2004). When data for quantitative methods like systematic conservation planning and threshold analysis are not available, heuristic principles may be used to design MPAs that protect biodiversity and ecosystem services (Rondinini and Chiozza 2010). These principles include expert knowledge and rules of thumb, and while such principles are subjective to a degree, they should always be rooted in scientific knowledge. Roberts et al. (2003) provided a comprehensive framework of science-based criteria for the selection of candidate MPA sites and the development of MPA networks. Their criteria for effective MPA network design included: representation of all biogeographic regions and habitats; consideration of human threats and natural catastrophes; MPA size that sustains viable population and acts as a buffer for disturbances; support of connectivity; protection of vulnerable habitats and life stages, species or populations of concern; preservation of ecosystem linkages and ecological services.

While ecological criteria like those proposed by Roberts et al. (2003) do not directly translate to quantitative targets for marine protection, these heuristic principles are useful to incorporate the qualitative attributes of MPAs indicated by protection targets (for example, considering Aichi Target 11, "*effectively and equitably managed, ecologically representative and well connected*" and "*integrated into the wider landscapes and seascapes*") in MPA planning processes.

Regardless of the method used to establish conservation targets, Svancara et al. (2005) found that policy-driven targets were, on average, close to the often-encountered figure of 10%, whereas science-based targets were on average three times higher (30–40%).

4. Scientific basis of coverage targets for marine protection

Scientific background to CBD decisions related to Aichi Target 11 has been provided by bodies like the CBD's Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA). In the seventh meeting of the SBSTTA (Montreal, Canada, 2001), a proposal for the Global Strategy for Plant Conservation contained the target of effectively conserving *in situ* 10% of each of the world's ecological regions, coupled with 50% of the world's threatened species[2]. Three years later, decision VII/30[3] of the Seventh Conference of the Parties to the CBD (Kuala Lumpur, Malaysia, 2004) included a provisional framework for goals and targets for the conservation of biodiversity (Annex II), with Target 1.1 of having, by 2010, "*At least 10% of each of the world's ecological regions effectively conserved*". A document[4] outlining the development of the targets for protected areas proposed in decision VII/30 pointed out that Target 1.1 was already applied in the Global Strategy for Plant Conservation (as Target 4), and was "*proposed to be integrated into the programme of work on protected areas and applied to all thematic programmes, including those on Marine and Coastal Biodiversity and Inland Water Biodiversity*". In a following meeting of the SBSTTA (tenth meeting, Bangkok, 2005) the report of the Expert Group on Outcome-Oriented Targets (UNEP/CBD/SBSTTA/10/INF/6[5]) outlined that, with respect to coastal and marine areas, "*The 10 per cent target adopted by the seventh meeting of the Conference of the Parties in decision VII/30 was originally conceived for 2-dimensional terrestrial systems*", and that the 10% target for marine areas was lower than the optimum 20–30% indicated in recent scientific literature. As a result, the 10% target for marine areas should have been viewed as "*an intermediate, policy-relevant, target, while the needs for long term protection would be determined taken into account the status and unique characteristics of each ecological region*". While contributions[6] of the SBSTTA to drafts of the CBD's Strategic Plan for Biodiversity presented alternative values of coverage targets for coastal and marine areas (6%, 10%, and 15%), 10% was retained for Aichi Target 11.

[2] https://www.cbd.int/doc/meetings/sbstta/sbstta-07/official/sbstta-07-10-en.pdf
[3] https://www.cbd.int/doc/decisions/cop-07/cop-07-dec-30-en.pdf
[4] https://www.cbd.int/doc/meetings/cop/cop-07/official/cop-07-20-add3-en.pdf
[5] https://www.cbd.int/doc/meetings/sbstta/sbstta-10/information/sbstta-10-inf-06-en.pdf
[6] https://www.cbd.int/doc/meetings/cop/cop-10/official/cop-10-03-en.pdf

Despite these reports of the contribution of scientific working groups to the formulation and subsequent revision of coverage targets, some authors have highlighted limited scientific justification for international targets like Aichi 11 (Carwardine et al. 2009). In this section, we provide an overview of the scientific evidence in support of coverage targets for marine protection.

4.1. Previous reviews

Previous reviews have considered the scientific basis for MPA coverage targets (Roberts and Hawkins 2000, Gell and Roberts 2003, Gaines et al. 2010, O'Leary et al. 2016), often with a dual focus on protection of biodiversity and the effects of MPAs on extractive activities. Although the CBD indicates that the development of MPA networks should be conservation-driven (CBD 2010), MPA planning must often consider the relationships between MPAs and extractive activities, in particular fisheries. As a consequence, beneficial effects of MPAs on fisheries are often included as a secondary goal in MPA planning.

Extensive research has highlighted the beneficial effects of MPAs on biodiversity, abundance, and biomass of species, and on the human uses of the ecosystems, including fisheries. For example, even partially protected MPAs (i.e. MPAs that allow for some extractive activity) have some positive effects on fish density and biomass (Sciberras et al. 2013, Giakoumi et al. 2017, Zupan et al. 2018), compared to open-access areas. Previous reviews have also highlighted positive effects of MPAs on fisheries, for example via spill-over of biomass or larvae of targeted species from some MPAs to fished areas (reviewed in Goñi et al. 2011). However, generalising the benefits of partially protected MPAs on biodiversity is difficult, because levels of protection are not the same for all MPAs (Lester and Halpern 2008). Many studies have shown that no-take MPAs (marine reserves) have the most benefits for biomass, abundance, species richness, and body size of protected animals (e.g. Lester et al. 2009, Costello 2014, Costello and Ballantine 2015, Sala and Giakoumi 2017). However, it has been contended that establishing no-take MPAs alone is not sufficient to benefit biodiversity (Roberts and Hawkins 2000, Gell and Roberts 2003), that MPAs have beneficial effects on fisheries mostly in overfished or poorly managed systems (Hilborn 2018), and that efficient management of areas outside MPAs is also required to meet conservation and fishery needs (Hilborn et al. 2004).

Roberts and Hawkins (2000) reviewed a number of (mostly modelling) studies that quantified the no-take MPA coverage required to achieve different objectives. Objectives included: ethical obligation for conservation; minimisation of stock collapses; enhancement of long-term fishery yield; ensuring sufficient connectivity to support biodiversity; and allowing resilience from catastrophic events. Although different objectives required different coverage targets, 20–50% MPA coverage was required to avoid stock collapse, and 20–40% was required to increase long-term fishery yield. In agreement with these figures, Gell and Roberts (2003) reported that the most benefits to fisheries revenues had been observed for closure of 10–35% of fishing grounds in several geographic locations, including Apo Island (Philippines), Georges Bank (NE United States), and St Lucia (Caribbean). However, these studies also highlighted that MPA coverage is only one of the aspects that determine the effectiveness of MPA networks in achieving conservation and socioeconomic objectives. For example, the size of individual MPAs is important to ensure connectivity between MPAs in a network (Roberts and Hawkins 2000), and a reduction of fishing efforts and destructive fishing methods must complement the designation of MPAs for effective marine conservation (Gell and Roberts 2003).

Gaines et al. (2010) challenged the perception that there is a trade-off between biodiversity conservation and fishery revenues, showing that these two goals overlap substantially. They examined 33 modelling studies that tested the effects of marine reserves on fishery yields. They found that benefits on fishery yield and/or profits were maximised for as much as 50% of the total area protected within marine reserves. Larger proportions of protected area, while beneficial to conservation, may no longer offset the loss in revenues deriving from the displacement of fisheries. However, Gaines et al. (2010) also emphasised that the size of the region to protect depends on other fishery management practices, and that overexploited, or poorly managed areas will typically benefit the most from MPAs.

O’Leary et al. (2016) conducted a systematic review of evidence-based coverage targets for marine protection, with the goal of quantifying which targets are required to achieve, maximise, or optimise conservation objectives. Reviewing 144 studies (most of which were modelling frameworks like gap analyses, species-area relationships, and numerical simulations), they identified six main objectives of marine protection, and estimated how often such objectives are met if different MPA coverage targets are enforced. These objectives were: (1) to protect biodiversity; (2) to ensure connectivity between MPAs; (3) to minimize the risk of stock collapses; (4) to mitigate the evolutionary effects of fishing; (5) to maximise fishery yield; and (6) to benefit multiple stakeholders. O'Leary et al. (2016) found that an MPA coverage of 10% achieved the objective in only 3% of the studies. More than half of the studies they reviewed showed that the objectives could be met for ≥30% marine protection. Although O'Leary et al. (2016) possibly oversimplified the results from some of the studies they considered by extrapolating summary statistics for broad ranges of conservation targets (White et al. 2017), their results are in agreement with targets of 20–50% recommended by previous studies (e.g. Roberts and Hawkins 2000, Gell and Roberts 2003, Gaines et al. 2010).

4.2. Review of recent (2016 – 2020) studies

We followed a similar protocol to O'Leary et al. (2016) and conducted a systematic review of the studies that identify minimum effective targets for MPA coverage published during the period 2016 – March 2020. The purpose of this review was to summarise recent developments in assessing the effectiveness of coverage targets for marine protection, updating the detailed overview of O'Leary et al. (2016) and aiding future discussion related to post-2020 global conservation targets and domestic targets for marine protection.

4.2.1. Article search and selection

To identify studies that evaluate the performance of coverage targets in achieving conservation and stakeholders' objectives, we used search methodologies similar to O'Leary et al. (2016). First, we conducted a Scopus search (searched on March 29th 2020) using the same search string used by O'Leary et al. (2016), which contained a set of relevant search words including "Marine Protected Area", "Objective", and "Optimise" (see Appendix 1 for the full string). We ran the search only on records' titles, abstracts, and keywords, but not on full texts. We limited the search to records published over the period 2016 – 2020, because O'Leary et al. (2016) searched for studies published until the end of 2015. We could not follow the protocol used by O'Leary et al. (2016) for their searches on Web of Science due to time constraints, but our Scopus search and later additional searches (see below) yielded a final number of 4.6 studies per year, comparable to 6 studies per year of O'Leary et al. (2016).

The first Scopus search returned 213 studies. We screened these studies with the same criteria used by O'Leary et al. (2016). In brief (see Methods section in O'Leary et al. 2016 for details), to be included in our review, studies had to focus on the marine environment (at any geographic location or theoretical), and they had to indicate which percentage of the study area should be protected within MPAs in order to achieve, maximise, or optimise predefined objectives. We screened the 213 studies with a hierarchical method as described by O'Leary et al. (2016): studies that appeared not relevant from their title and abstract were excluded from further consideration. After reading the full text of the remaining studies (n = 36), we excluded from further consideration another 15 studies which did not meet the criteria outlined above (for example studies which supported the expansion of MPA coverage to achieve some objective but did not provide the percentage of the study area to be protected). Bibliographies of the studies that were considered in depth were also searched for relevant articles for the period 2016 – 2020, to be added to the 213 studies returned by the first Scopus search. After all searches, a total of 23 studies met the criteria to be included in our analysis.

4.2.2. Data handling

For each study included in the analysis, we categorised the objectives of establishing MPAs, building on the classification used by O'Leary et al (2016). From that study, we retained: to protect biodiversity; to ensure connectivity; to avoid collapse; to enhance fishery value; and to satisfy multiple stakeholders. O'Leary et al. (2016) also considered the objective of avoiding the adverse effects of fishery-induced evolution, but we found no study focusing on this objective, and therefore we excluded it from our classification. However, we found studies focusing on the objective of mitigating the effects of climate change, or of ensuring ecosystem resistance and resilience to climate change. There is a growing consensus that nature conservation has an important role in safeguarding ecosystems from climate change effects (Roberts et al. 2017), and that targets for biodiversity conservation and targets for climate change mitigation should be coupled (Dinerstein et al. 2019). Therefore, we also considered the objective of "resistance to climate change". Finally, we identified studies that indicated minimum MPA coverage needed to achieve a set of multiple objectives at the same time. These were often modelling studies that tested multiple scenarios of protection and management with the goal of maximising conservation and commercial uses (e.g. Timonet and Abecasis 2020). Therefore, we defined the category of “multiple objectives”.

Some studies reported ranges of targets for marine protection, which depended on different model formulations and on the evaluation of a number of scenarios of conservation and exploitation. The study from O’Leary et al. (2016) has been criticised for summarising ranges of coverage targets with summary statistics (like median values) where the purpose of the original studies was to test a range of models or scenarios (White et al. 2017). Here, we used single values of MPA coverage to summarise ranges when these values were proposed by the authors of the original article. For example, Drira et al. (2019) calculated a range of coverage targets for the protection of fish biodiversity in the Mediterranean Sea by using a set of species-area relationship models, but they also highlighted that “*Using multi-model inference resulted in a mean conservation target of c. 38% over the entire study area. This conservation target* […] *promotes both species representation and persistence within each habitat*”. For two studies that quantified required MPA coverage under combinations of different management scenarios and fishery regimes (Timonet and Abecasis 2020, Vilar et al. 2020), we summarised the resulting range of conservation targets with the median. While we recognise that this may oversimplify the nuances conveyed by the original studies, we believe that the chosen median values were an acceptable representation of the range presented by the authors in these two instances. To capture the variability that was lost by summarising studies with single values of MPA coverage, Table A2 shows which studies considered the effectiveness of ranges of MPA coverage values (even when these were reported by the authors of the original study).

4.2.3. Results and discussion

We retained a total of 23 studies reporting effective area-based targets for marine protection (Table A2 in Appendix 2). Of these studies, 16 used modelling approaches (including species-area relationships, GIS modelling, and other numerical models); four used heuristic principles and review of the ecology of a region and its resources; two used mark-and-recapture methods; and one used a stakeholder-driven process. Because some of these studies considered more than one objective for establishing MPAs, we obtained a total of 38 objectives from the 23 studies (Fig. 1-a). Of the 23 studies, 17 reported ranges of MPA coverage required to achieve given objectives (Table A2), for example as a result of different model formulations (Davis et al. 2017, Drira et al. 2019) and scenarios that modelled different levels of fishing pressure (Chollet et al. 2017) or different levels of protection (Timonet and Abecasis 2020).

Only one of the 38 objectives (avoiding species collapse) was achieved with 10% MPA coverage, while approximately 60% of MPA objectives were achieved with 30% MPA coverage and approximately 80% of objectives were achieved with 50% MPA coverage (Fig. 1-b). This is similar to the result of O'Leary et al. (2016), who reported that over half the studies they considered called for >30% MPA coverage to achieve their objectives. The small sample size of the data set considered for this review did not allow statistical testing of the targets between objectives, as conducted by O'Leary et al. (2016).

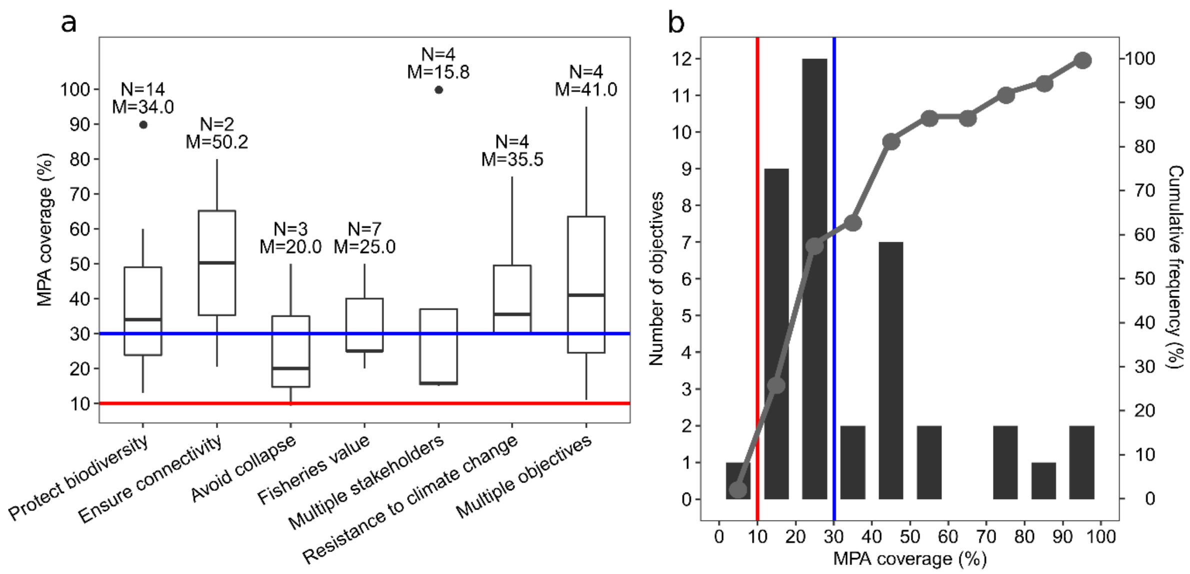

Figure 1. a: Boxplot of the area-based conservation targets (expressed as marine protected area percentage cover) required to achieve conservation and socio-economic objectives. Solid lines within boxes indicate the median. Lower and upper hinges correspond to the first and third quartiles, respectively. Lower (and upper) whiskers extend from the lower (and upper) hinges to the smallest (and largest) value no further than 1.5 * IQR from the hinge (where IQR is the inter-quartile range, i.e. the distance between the first and third quartiles). Dots represent outliers. For each objective, median values (M) and number of studies investigating the objective (N) are reported. b: Frequency distribution of the required MPA coverage to meet MPA objectives, based on the 38 objectives included in panel a. Cumulative frequency (%) (solid grey line with dots) showing the percentage of objectives that are met at each 10% increment of MPA coverage. Solid lines in both plots represent international targets of 10% (red) and 30% (blue) MPA coverage.

MPAs achieving objectives related to the protection of biodiversity (14 studies) had a median coverage of 34% (range 13–90%). However, specific objectives that fell in this category varied greatly between studies. For example, considering three gap analyses: a global analysis (Davidson and Dulvy 2017) showed that protecting the extent of occurrence of 99 species of imperilled endemic chondrichthyans required protecting 13% of the world's ice-free EEZ; a study from the Ningaloo Marine Park (Australia) predicted the need for 45.8% MPA coverage to protect a predetermined proportion of the spatial extent of each benthic habitat, which included shallow water invertebrates like hard corals, sponges, and soft corals (Davies et al. 2016); and a study from Brazilian coral reefs predicted the need of ~90% MPA coverage to protect variable proportions of each ecosystem type and the area of occurrence of each of 405 reef fish species (Magris et al. 2017). Similarly, MPA coverage for individual objectives pertaining to the protection of fishery values (seven studies) was also highly variable, and dependent on other forms of fishery management in areas open to fisheries. For example: 20% no-take MPA coverage provided the highest yield of spiny lobster fisheries in the Caribbean under moderate values of fishing mortality, while avoiding stock collapse (Chollet et al. 2017); but a network of reserves covering up to 50% of the local coral reef areas was necessary to double the catch of coral trout fisheries in Indonesia (Krueck et al. 2019).

These examples illustrate that coverage targets for marine protection depend on the specific objectives of the MPA network. In general, narrow and specific objectives like avoiding the collapse of one or few species required lower MPA coverage than broader objectives of ensuring connectivity and resistance to climate change. For example, Waldie et al. (2016) found that no-take protection of approximately 10% of the catchment area of a grouper off a small tropical island would protect 30–50% of the grouper's spawning population throughout the non-spawning season. Conversely, protecting an array of ecosystem types, functional groups, and threatened species, while ensuring connectivity between MPAs and safeguarding habitats that can offer refugia from climate change required protecting over 90% of coral reefs in Brazil (Magris et al. 2017). O'Leary et al. (2016) also highlighted the large variability in MPA coverage required to achieve conservation and stakeholders' objectives, suggesting that extreme targets (near 0 and 100%) often correspond to single or narrow conservation goals. Here, we found the only instance that required 100% MPA coverage was a case where fishermen profited from tourism revenues of a no-take marine reserve, which is, indeed, a single and narrow objective.

In the studies we considered, MPA coverage required to meet conservation and stakeholder's objectives also depended on contextual ecological features of the study area. For example, a relatively low MPA coverage of 15% of Finland's territorial sea and EEZ captured 80% of the distribution of the biodiversity features to protect, because benthic biodiversity in the Baltic Sea is relatively concentrated in shallow coastal areas, with large deeper areas supporting low benthic biodiversity due to low oxygen levels (Virtanen et al. 2020). Consequently, it is important to also evaluate the relevance of coverage targets to the ecological context they will be applied to.

Importantly, coverage targets for MPA networks should be complemented by qualitative attributes that underpin MPA effectiveness (Rees et al. 2018). For instance, Aichi Target 11 acknowledges that in addition to meeting coverage targets, MPA networks need to also be representative and well-connected to ensure they are effective in meeting their conservation goals. Representativeness of MPA networks is important to achieve effective protection, and a number of gap analyses have highlighted shortcomings in the representativeness of systems of MPAs in cases where total MPA coverage meets quantitative targets (e.g. Barr and Possingham 2013, Foster et al. 2017, Jessen et al. 2019,). Considering the objective of protecting biodiversity features, many of the approaches we reviewed aimed to protect, equally, given proportions of each habitat, ecosystem type, or ecoregion that occurred in the study domain (Davies et al. 2016, Magris 2017, Munguia-Vega et al. 2018, Roberts et al. 2020, Timonet and Abecasis 2020). Pursuing area-based targets in isolation may lead to the investment of limited resources in establishing "residual" MPAs (see below) that are not representative and only contribute towards coverage targets (Agardy et al. 2003, 2006, Devillers et al. 2015; see Section 5 of this report).

5. Criticisms of coverage targets

Coverage targets for biodiversity protection have been criticised as sources of perverse outcomes (Agardy et al. 2003, 2016, Carwardine et al. 2009, Visconti et al. 2019). Here, we provide a brief overview of the main arguments against using coverage targets in conservation efforts.

5.1. Residual MPAs: quantity vs quality

While the formulation of Aichi Target 11 contains qualitative attributes for protected areas, including "*effectively and equitably managed, ecologically representative and well connected*", nations rushing to meet quantitative area-based targets may neglect quality of marine protection in favour of quantity (Agardy et al. 2016). A well-recognised issue with area-based conservation is the establishment of "residual" MPAs (Devillers et al. 2015). These protected areas are designated in areas that are hardly used for extraction purposes, with no real conservation objective and a primary purpose of meeting internationally mandated area-based targets for protection. A recent gap analysis highlighted that the global MPA network is largely residual, with MPAs placed in areas that are unsuitable for other human uses (Jantke et al. 2018).

Notably, the residual nature of MPA networks has been attributed to the rapidly increasing designation of large-scale MPAs (LSMPAs) over the last two decades (Devillers et al. 2015). The global impact of human activities on the oceans is heaviest in coastal seas (Halpern et al. 2008), and many marine species that do not benefit from any protection are distributed in EEZ areas (<200 nautical miles from the coast), highlighting the need for protection of these parts of the oceans (Klein et al. 2015). However, designating MPAs in remote locations where few stakeholders have interests encounters much less resistance than displacing existing commercial and recreational activities, which more frequently occur in coastal waters. Some countries have been establishing large remote MPAs overseas, or around remote islands (O'Leary et al. 2018). While these MPAs may provide much needed protection for some pristine or unexploited remote ecosystems (for example New Zealand's offshore islands), they may provide an overly optimistic depiction of countries' progresses against goals of protecting a representative range of marine habitats, including those in coastal waters (Jones and De Santo 2016). There are often substantial knowledge gaps about the ecology of remote marine areas designated for protection (O'Leary et al. 2019), and it has been suggested that establishing LSMPAs is sometimes a political rather than evidence-based process (Leenhardt et al. 2013). However, LSMPAs represent an opportunity for proactive rather than reactive protection, and do have a number of ecological and socioeconomic advantages (O'Leary et al. 2018).

5.2. Effective protection

The term MPA has been used loosely, and it does not always entail actual and effective protection (Sala et al. 2018). The IUCN has developed a standard of protection that assigns protected areas to one of seven categories (Ia, Ib, II–VI), depending on the levels of protection from extractive activities that the area offers (Day et al. 2012). Categories Ia and Ib offer the highest level of protection, and categories II–VI offer decreasing levels of protection, allowing different kinds of regulated and sustainably managed activities. While the IUCN standard is useful for comparing protected areas between countries, the standard is often applied differently by different nations, and minimum internationally agreed-upon standards of protection are lacking (Jessen et al. 2017). As a result, national reporting against IUCN categories Ia, Ib, and II, which offer the highest level of protection, has included areas allowing a range of commercial extractive activities (e.g. Robb et al. 2011).

It has been stressed that the key objective of establishing MPA networks should be that of protecting biodiversity (CBD 2010). However, because fisheries are one of the main uses of marine resources, conservation of the seas and fishery management are inevitably closely-interconnected processes (Gaines et al. 2010). Some fishery management areas may be considered a type of MPA, and therefore could count towards meeting international conservation targets. In New Zealand for example, MPA protection standards (Ministry of Fisheries and Department of Conservation 2008) include areas where certain fishery restrictions are enforced, submarine cable protection zones, marine mammal sanctuaries, and other areas protected under other legislations as MPAs, provided that all these areas meet minimum protection requirements according to scientific evaluation (Department of Conservation and Ministry of Fisheries 2011). Similarly, some Canadian jurisdictions have elected to classify some fishery closures (areas where some types of commercial fishing, such as the use of destructive bottom gear, are prohibited) as "marine refugia", and to classify these as examples of "*other effective area-based conservation measures*" included in the formulation of Aichi Target 11 (Lemieux et al. 2019). While in 2019 Canada has closed its MPAs to a range of commercial extractive activities, including bottom trawling and mining (Devillers et al. 2019), it has been argued that fishery closures often do not share the goals nor satisfy the protection requirements of MPAs, and should not be counted against meeting international targets (Lemieux et al. 2019).

While some authors advocate for the use of fishery management to protect biodiversity and maintain fisheries, rather than closing off areas to fishing and displacing fisheries elsewhere (Hilborn 2018), counting fishery management areas as MPAs has been criticised for confusing conservation needs with commercial interests (e.g. Sala and Rechberger 2018), and some conservation scientists indicated that establishing fully no-take MPAs is the most effective approach to the protection of biodiversity (Costello and Ballantine 2015).

There is extensive scientific evidence for the effectiveness of no-take marine reserves in meeting some biodiversity objectives. A recent meta-analysis found that fish biomass is frequently larger inside no-take MPAs than in other MPA types and open access coastline (Sala and Giakoumi 2017), supporting the results of past reviews that have found that no-take marine reserves have positive effects on the biomass, density, and species richness of the protected communities (Lester et al. 2009). In New Zealand, no-take marine reserves have been found to often have greater benefits for biodiversity than multiple-use MPAs (Costello 2014). However, these benefits can depend on the placement and the ecological features of the protected areas, including habitat complexity (Jack and Wing 2010) and potential for larval supply (Freeman et al. 2012). This reiterates the importance of careful MPA planning in achieving effective protection.

Edgar et al. (2014) identified "*no-take*" as one of five attributes that maximise the ecological performance of MPAs, with the other four being "*enforced*", "*old*" (>10 years), "*large*" (>100 km^2), and "*isolated*" by sand or deep water. Qualitative attributes of an MPA, like habitat representativeness, its potential to recover from natural and human threats, and its connectivity with other MPAs, help guarantee the biological integrity of an MPA and are important in driving MPA planning (Roberts et al. 2003). Finally, effective MPA management is fundamental for the achievement of the conservation objectives, with staff and budget capacity of MPAs being strong predictors of conservation impact (Gill et al. 2017).

Overall, meeting coverage targets alone is not sufficient to fulfil conservation goals. Coverage targets for marine protection must be completed by qualitative attributes that define which features the quantitative targets should be applied to, and that prescribe standards of effective protection and management.

6. Coverage targets in New Zealand and selected countries

Over the last two decades, international targets (both quantitative and qualitative) have been important in driving global efforts in marine management. However, many countries have also adopted national conservation targets tailored to their domestic ecological and socioeconomic context. For countries that are parties to the CBD, this process was encouraged by the CBD's request of developing national biodiversity strategies after the Earth Summit in Rio De Janeiro (1992).

In this section, we review the coverage targets adopted by New Zealand and four countries that have comparable ecological and socioeconomic settings: Australia, Canada, the United Kingdom (UK) and the United States (US). We chose these countries for four reasons: (1) their marine areas include temperate ecosystems comparable to New Zealand; (2) they provide examples of different processes for setting coverage targets for MPA networks, with some of these countries adopting national targets (New Zealand, Australia, and Canada), and one not bound to report against CBD targets (the US, the only one of these countries that is not a party to the CBD); (3) they are all developed countries with comparable access to financial resources for MPA planning and management; and (4), when considering the Overseas Territories of the UK, all these five countries have MPAs in the Pacific Ocean, thus potentially being interconnected in the scope of a global MPA network.

We focus on the coverage targets and on their qualitative attributes that countries have adopted, and on how these targets are related to Aichi Target 11. We then provide examples of the scientific advice that countries have used to set their coverage targets, or to evaluate their effectiveness. To identify which coverage targets have guided marine protection in New Zealand, Australia, Canada, and the UK, we consulted these countries' Sixth National Reports to the CBD. In these official documents produced by national governments, the parties to the CBD reported on their management of natural resources over the period between 2014 and 2018, and presented their progress towards meeting national and international conservation targets. From the Sixth National Reports to the CBD, we identified the policies that define MPA coverage targets in each country (e.g. biodiversity strategies, MPA management plans, etc.). Where possible, we identified in these policies (and in other relevant documents) examples of the scientific processes that have informed the definition of coverage targets in each country, or that have evaluated the effectiveness of such targets. Because the US is not a party to the CBD, we obtained information on coverage targets and their scientific basis in the US from publicly accessible websites of US government bodies, such as the National Oceanic and Atmospheric Administration (NOAA).

6.1. New Zealand

Adopted targets

New Zealand established national conservation targets in its Biodiversity Strategy (the Strategy, New Zealand Government 2000) and its updated Action Plan (New Zealand Government 2016). In New Zealand's Biodiversity Strategy 2000 (the Strategy, New Zealand Government 2000), Objective 3.6 of "*Protecting marine habitats and ecosystem*" required "*a target of protecting 10 percent of New Zealand's marine environment by 2010 in view of establishing a network of representative protected marine areas*" (Action 3.6b). Therefore, Objective 3.6 of Strategy contained an explicit numeric target for the extent of marine protection in New Zealand.

To facilitate meeting Objective 3.6 of the Strategy, the Marine Protected Areas Policy and Implementation Plan 2005 (the Policy, Department of Conservation and Ministry of Fisheries 2005) was adopted to guide the establishment of a network of MPAs in New Zealand's territorial sea and EEZ. Regarding Action 3.6b and the 10% target for marine protection, the Policy stated that the 10% target will be an important indicator of New Zealand's progress in developing its MPA network, but that the ultimate extent of protection should be determined by what coverage will be needed to "*establish a comprehensive and representative network*" of MPAs[7]. This has two implications. First, the Policy highlighted that qualifiers like "*comprehensive*" and "*representative*" should guide MPA planning in New Zealand. Second, that the 10% coverage target, while useful to track progress, is neither sufficient nor required to meet the conservation objective of building an MPA network, and that meeting it should not be the ultimate goal of MPA planning. The Policy set a number of principles for network design, which included MPA size adequate to sustain biologically viable populations,

[7] Action 3.6(b) will be important as an indicator of progress towards achieving marine biodiversity protection. However, the ultimate extent of protection will be determined by what coverage is required to establish a comprehensive and representative network of marine protected areas. Department of Conservation and Ministry of Fisheries (2005).

connectivity between MPAs, replication of MPAs to ensure the preservation of ecosystem processes, and representativeness of MPAs.

The Policy was followed by the MPA Classification, Protection Standard and Implementation Guidelines 2008 (the Guidelines, Ministry of Fisheries and Department of Conservation 2008). The Guidelines had the purpose of providing a classification system for marine habitats built on scientific advice, as well as protection standard for MPAs in New Zealand and guidelines to plan and implement an MPA network. The Guidelines also noted that targets for marine protection needed to meet the goals of the Strategy of having a comprehensive and representative network of MPAs should be subject to review as new scientific information becomes available. Thus, both the Policy and the Guidelines reiterated the 10% target adopted by the strategy, but suggested that MPA coverage may ultimately vary with respect to that target.

Recent developments of New Zealand conservation policy do not include a specific target for MPA coverage in their formulation. New Zealand Biodiversity Action Plan 2016 – 2020 (the Plan, New Zealand Government 2016) is an update to the Strategy and it contains a set of 18 national targets that aim to guide New Zealand in achieving six conservation goals[8]. National Target 13, which is part of Goal C, "*Safeguarding ecosystems, species and genetic diversity*", calls for "*A growing nationwide network of marine protected areas, representing more of New Zealand's marine ecosystems*". Three key actions are detailed in the Plan to work towards meeting Target 13: the establishment of new marine protection legislation to be used as framework to establish and expand the MPA network; the inclusion of a wider range of marine ecosystems in MPAs; and the establishment of the Kermadec / Rangitahua Ocean Sanctuary. While the formulation of Target 13 does not contain an explicit numeric attribute for the extent of the MPA network, this target is presented as directly related to Aichi Target 11 both in the Plan and in New Zealand's Sixth National Report to the CBD (Department of Conservation 2019). Therefore, New Zealand still strives to meet Aichi Target 11 in its quantitative and qualitative components.

[8] Goal A: Mainstreaming biodiversity across government and society. GOAL B: Reduce pressures on biodiversity and promote sustainable use. GOAL C: Safeguarding ecosystems, species and genetic diversity. GOAL D: Enhance the benefits to all. GOAL E: Enhance implementation. New Zealand Government (2016).

Importantly, the Guidelines also set protection standards for New Zealand's MPAs. The Guidelines identified two types of MPAs: Type 1 MPAs, or no-take Marine Reserves, typically established under Marine Reserves Act 1971[9] but also under special legislation; and Type 2 MPAs, as other MPAs that may be created under Fisheries Act tools or other relevant legislation, including the Resource Management Act and the Wildlife Act, and may allow some types of extractive activity. In addition, the Guidelines identified as Other Protection Tools areas that are under some protection (for example the restriction of some extractive activities), but do not meet the MPA protection standard. While only the first two types can be considered MPAs, it is stated in the Policy that "*All forms of marine protection* […] *are relevant when measuring progress towards the NZ Biodiversity Strategy target*" (see Section 7.1).

Scientific support

The numeric target of 10% MPA coverage in New Zealand's marine environment adopted in the Strategy is underpinned by limited domestic scientific information. In response to the Policy's call for the identification of gaps in New Zealand's MPA network, a gap analysis was carried out to assess the extent and the representativeness of Type 1 MPAs (no-take reserves) and Type 2 MPAs (multiple-use MPAs) in New Zealand's territorial sea (<12 nautical miles from the coast and the islands) (Department of Conservation and Ministry of Fisheries 2011). That study identified protection gaps in New Zealand's MPA system, with MPAs representing large areas in the Kermadec Island and Subantarctic Islands bioregions and very small areas (<1%) of other bioregions. Furthermore, reviewing the effectiveness of benthic protected areas within New Zealand's EEZ with the spatial planning software Zonation (Moilanen et al. 2005), Leathwick et al. (2006) demonstrated that increasing MPA coverage to 20–30% of New Zealand's EEZ would increase average species protection of demersal fish species by up to 50%, and that such an expansion of the MPA network could be done with minimal impacts on the fishing industry if appropriate decision support tools were used (Leathwick et al. 2008). These studies have shown that MPA coverage alone is of limited importance in achieving conservation goals and highlight the importance of the qualitative attributes of MPA networks detailed in the Policy and the Guidelines.

[9] http://www.legislation.govt.nz/act/public/1971/0015/latest/DLM397838.html

6.2. Australia

Adopted targets

Over the 2014 – 2018 period covered by the Sixth National Report to the CBD (Government of Australia 2020), Australia has pursued national targets for conservation defined in Australia's Biodiversity Conservation Strategy 2010 – 2030 (ABCS, Government of Australia 2010). ABCS identified three main conservation priorities: to engage all Australians; to build ecosystem resilience in a changing climate; and to get measurable results. To guide actions to achieve these conservation priorities, ABCS set 10 interim targets to be met by 2015. Because ABCS was released before the CBD's SPB 2010 – 2020, Australia's 10 interim targets were not based on the 20 Aichi Targets.

The use of coverage targets for MPA planning has not been Australian policy[10]. The 10 interim targets presented in ABCS included a number of numeric targets, including area-based targets like interim targets 4[11] and 5[12], which were in the scope of protecting biodiversity and maintaining and re-establishing ecosystem functions. These targets, the progress against which was reported in Australia's Sixth National Report to the CBD (Government of Australia 2020), did not express protected area percentage coverage, and rather identified a minimum increase of the area to be protected. Furthermore, they did not indicate the contribution of terrestrial, freshwater, and marine ecosystems to the total area increase. These limitations to the interim targets, and the need of better aligning Australia with international goals were highlighted in Australia's Sixth National Report to the CBD (Government of Australia 2020).

ABCS was reviewed and the new Australia's Strategy for Nature 2019 – 2030 (ASN, Government of Australia 2019) was adopted. No explicit numeric targets are presented

[10] Guidance on Achieving Comprehensiveness, Adequacy, and Representativeness in the Commonwealth waters component of the National Representative System of Marine Protected Areas. The Scientific Peer Review Panel for the National Representative System of Marine Protected Areas. Available at https://parksaustralia.gov.au/marine/management/resources/scientific-publications/guidance-achieving-comprehensiveness-adequacy-and-representativeness-commonwealth-waters/

[11] By 2015, achieve a national increase of 600,000 km^2 of native habitat managed primarily for biodiversity conservation across terrestrial, aquatic and marine environments. Government of Australia (2010).

[12] By 2015, 1,000 km^2 of fragmented landscapes and aquatic systems are being restored to improve ecological connectivity. Government of Australia (2010).

in ASN, but Objective 5[13] calls for an improvement in the number, extent, representativeness, connectivity, and capacity of government-managed, indigenous, and private protected areas. Objective 5 is mapped to Aichi Target 11 in ANS, but its formulation does not include the 10% area-based component.

Australia's Sixth Report to the CBD (Government of Australia 2020) indicated that, over the 2014 – 2018 period, Australia still implemented the Strategic Plan of Action for the National Representative System of Marine Protected Areas (SPANRSMPA, ANZECC TFMPA 1999) to facilitate the creation of a comprehensive and representative MPA system. In alignment with the later ABCS and its update, SPANRSMPA did not prescribe explicit MPA coverage targets. Instead, it recommended that future studies would be needed to constantly evaluate and adapt the appropriate extent of an MPA network that contributes to the "*long-term ecological viability of marine and estuarine systems, maintain ecological processes and systems, and protect Australia's biological diversity at all levels*".

Scientific support

Because Australia does not currently have a specific coverage target for MPAs, we were unable to determine the availability of any scientific information supporting a coverage target. However, we note that every five years the Australian Government commissions a review of the state of the environment in Australia, with the most recent in 2016 (Cresswell and Murphy 2017). These usually represent a comprehensive review of scientific literature and analysis of new data sources, and have the purpose of identifying the pressures that affect biodiversity, assessing the state and the trends of biodiversity, and reviewing the effectiveness of biodiversity management. The State of the Environment Reports in Australia informed ABCS (Government of Australia 2010), and have since been used to identify the information gaps to be addressed in order to improve biodiversity management (Government of Australia 2020). Therefore, these assessments are useful to adaptively inform the appropriate quantitative and qualitative targets of the Australian MPA network, as recommended by the SPANRSMPA.

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[13] Improve conservation management of Australia's landscapes, waterways, wetlands and seascapes. Government of Australia (2019).

6.3. Canada

Adopted targets

In 2015, the Canadian Government released a set of 19 targets for biodiversity conservation, which had the purpose of mapping the 20 Aichi Targets to Canada's ecological context (Environment and Climate Change Canada 2016). Canada Target 1 prescribed that "*By 2020, at least 17 percent of terrestrial areas and inland water, and 10 percent of coastal and marine areas, are conserved through networks of protected areas and other effective area-based conservation measures*". Thus, Canada Target 1 retained the area-based components of Aichi Target 11 for both terrestrial and marine ecosystems. However, some authors have noted that the formulation of Canada Target 1 did not include the qualitative attributes of protected areas networks of Aichi Target 11[14] (Lemieux et al. 2019). This shortcoming of the formulation of Canada's Target 1 was acknowledged in the Sixth National Report to the CBD (Environment and Climate Change Canada 2018), which indicated that qualitative elements of Aichi Target 11 are considered in Canada's approach to biodiversity management but are not consistently monitored across the country (with the exception of representativeness). However, MPA planning in Canada is guided by the National Framework for Canada's Network of Marine Protected Areas (NFCNMPA, Government of Canada 2011), which provides a framework for designing an "*ecologically comprehensive, resilient, and representative national network of marine protected areas*", and covers the importance of considering representation, replication, adequacy, and connectivity in MPA planning (Schram et al. 2019). As such, NFCNMPA incorporates the internationally-defined qualitative attributes for MPAs that are not explicitly listed in the formulation of Canada Target 1.

Scientific support

The NFCNMPA provided eligibility criteria for MPAs, stating under the *Network Design* section that scientific guidance should be used for the identification of ecologically significant areas in need of protection, and for the configuration of the national MPA network. Fisheries and Ocean Canada provided a Science Guidance on the Development of Networks of Marine Protected Areas (DFO 2010), to achieve

[14] Effectively and equitably managed, ecologically representative and well-connected. CBD (2010).

consistency and effectiveness of MPA planning at national and regional levels. This document contained practical guidance for the selection of representative areas to be protected within MPAs. To this end, a two-step approach suggested in DFO (2010) is: (1) to estimate the MPA coverage that is required to approach the asymptote of species-area curves for the species composition of areas at large spatial scales (e.g. bioregion); and (2) to ensure that the MPA extent derived from step 1 encompasses areas of ecological significance (like areas important for biological productivity, or characterised by unique or fragile habitats, or threatened species). However, DFO (2010) did not attempt to justify the 10% target for marine protection adopted by Canada with Target 1.

Regional MPA planning processes in Canada have used systematic conservation planning approaches to design networks of protected areas. For example, MPA selection software Marxan (Ball et al. 2009) was used to aid in planning the appropriate extent and configuration of the MPA network in the Estuary and Gulf of Saint Lawrence (DFO 2014). Different values of MPA coverage (10%, 20%, and 30%) were tested to protect the spatial extent of features of interest like corals and sponge grounds in the Marxan analysis, but it was reported that there was a need of well-documented criteria for setting higher targets for protection. Other planning processes have used layers of geophysical data (like substrate composition, depth, exposure, and chlorophyll concentration), species and habitat distribution data, and ecological traits of species of interest to define maps of ecologically relevant areas to be used as conservation priorities in the Scotian Shelf Bioregion (DFO 2012) and in the Northern Shelf Bioregion (DFO 2017). Therefore, while scientific processes have not resulted in an explicit MPA coverage targets, scientific advice has informed MPA planning processes at regional level in Canada.

6.4. United Kingdom

Adopted targets

The UK has not developed national conservation targets, and reported its progress against the 20 Aichi Targets in the Sixth National Report to the CBD (JNCC 2019). Therefore, the coverage target for marine protection at national levels coincides with the 10% of Aichi Target 11. Biodiversity management and MPA planning in the UK are subject to layered jurisdictions, with a number of regional, national, European, and international agreements that guide conservation initiatives. Notably, a number of management tools that have guided nature conservation in the UK over the 2014 – 2018 reporting period are being, or may be, updated after the withdrawal of the UK from the European Union.

In the UK's Sixth National Report to the CBD (JNCC 2019) it was highlighted that the UK Post-2010 Biodiversity Framework (JNCC and DEFRA 2012) set out the priorities for biodiversity conservation in the UK over the 2010 – 2020 decade. At the level of the individual countries, England, Scotland, Wales, and Northern Ireland also have their own biodiversity strategies, which contain specific targets for MPA coverage and the principles for MPA planning and implementation. England's Biodiversity Strategy (DEFRA 2011), which had the purpose of guiding England's actions for the management of natural resources between 2010 – 2020, called for "*A more integrated large-scale approach to conservation on land and at sea*", with the identified priority of establishing and effectively managing an "*ecologically coherent*" MPA network protecting 25% of English waters by 2016[15]. Note that this 25% coverage target was not adopted by the UK at national level. Scotland's biodiversity strategy for 2020 (The Scottish Government 2013) outlined the target of protecting 10% of coastal and marine areas in MPAs by 2020[16] by developing an ecologically coherent MPA network in Scottish waters. Wales' biodiversity strategy (The Welsh Government 2015) did not prescribe a specific target for MPA coverage, but it reported that 35% of Wales' marine area already fell within MPAs. Similarly, Northern Ireland's biodiversity strategy (Department of the Environment 2015) did not prescribe an explicit coverage target for the MPA network, rather it highlighted the role of a coherent MPA network in achieving Good Environmental Status (GES), as required by European guidelines and legislation[17].

Scientific support

While at national level the UK has reported progress towards meeting Aichi Target 11 in international forums (JNCC 2019), the four countries have been striving to meet

[15] Priority action: Establish and effectively manage an ecologically coherent network of marine protected areas which covers in excess of 25% of English waters by the end of 2016, and which contributes to the UK's achievement of Good Environmental Status under the Marine Strategy Framework Directive. DEFRA (2011).

[16] Conserve at least 18% of land and inland water, and 10% of coastal and marine ecosystems, within protected areas by 2020. The Scottish Government (2013).

[17] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02008L0056-20170607&from=EN

different area-based targets, and pursued other conservation goals. One of the guiding principles of UK MPA policy over the 2014 – 2018 period was the achievement of Good Environmental Status (GES) of coastal and marine areas by the year 2020. Briefly, GES is a qualitative indicator of the state of the environment defined in the European Union's Marine Strategy Framework Directive[18], and it is based on a set of descriptors. In the UK Marine Strategy (DEFRA 2012, and its update in DEFRA 2019) MPA networks were recognised to play an important role in the achievement of GES with respect to three descriptors: biodiversity, food webs, and sea-floor integrity. The state of these descriptors is evaluated by measuring a set of environmental indicators, including habitat-related ones (such as habitat extent and habitat condition). The progress towards the achievement of GES has been typically evaluated by measuring whether indicators have a statistically significant departure from a baseline value, often referred to as Favourable Conservation Status[19]. To evaluate the conservation status and areal extent of habitat-based indicators, this is called Favourable Reference Area, defined as the "*Total surface area in a given biogeographical region considered the minimum necessary to ensure the long-term viability of the habitat type*" (European Commission 2005). Periodic assessments of the progress towards achieving GES have guided marine management plans in the UK (DEFRA 2012, 2019).

Previous studies have focused on coverage targets applied to the UK context. For example, with the use of habitat-specific species-area curves (see Section 3.1 of the present report), Rondinini (2010) identified habitat-specific conservation targets for MPA networks in UK marine and coastal areas. This study used habitat maps and records of marine species to parameterise species-area curves, suggesting that the obtained coverage targets should inform systematic conservation planning tools (like MPA selection software) in identifying optimal MPA configurations. The study from Rondinini (2010) did not attempt to provide one single coverage target for UK marine and coastal areas, but it quantified the proportion of marine species represented for different coverage targets. In addition, a number of gap analyses have addressed the coherence of MPA networks in UK marine and coastal areas. These analyses have shown that, while the area-based component of Aichi Target 11 has mostly been met

[18] https://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive/index_en.htm
[19] https://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm

at national level, there are protection gaps in the MPA network, which does not evenly represent all ecoregions and habitats (Foster et al. 2014, 2017).

6.5. United States

Adopted targets

The US is not a party to the CBD, and is therefore not bound to report its progress towards meeting the Aichi Targets. However, the US government acknowledges international targets like Aichi Target 11 (NMPAC – NOAA 2017), and previous reports on the state of the US MPA network have been put in the context of the 10% target. In the US, Presidential Executive Order 13158 (the Order, US Government 2000) mandated the development of a "*scientifically based, comprehensive national system of MPAs representing diverse U.S. marine ecosystems, and the Nation's natural and cultural resources*". The Order contained qualitative attributes for the national MPA network (including "*scientifically-based*" and "*comprehensive*") but did not set explicit coverage targets for such a network. The Order called for the development of a Framework for the National System of Marine Protected Areas of the United States of America (the Framework, NMPAC – NOAA 2008), which occurred between 2005 and 2008. The Framework had the purpose of guiding the development of the national MPA network, led by the National MPA Center (NMPAC) within the National Oceanic and Atmospheric Administration (NOAA). The Framework (and its update from 2015, NMPAC – NOAA 2015) presented the main goals of the US policy for MPA planning, which were the conservation of natural heritage, cultural values, and sustainable production of living resources and their habitats. These goals comprised of a number of more specific conservation objectives, which included, for example, to protect key reproduction areas and nursery grounds, areas of high species and/or habitat diversity, and key foraging grounds. The Framework also provided design and implementation principles for the national MPA network, but it did not mandate a spatial extent of such a network. Notably, the Framework prescribed that MPA design is guided by the principles of representativeness, replication, precautionary design, resilience, viability, and connectivity, thus aligning MPA planning criteria in the US with the guidelines of international targets.

Scientific support

A number of studies, both led by the US government and by external scientists, have considered the representativeness of the US national MPA network. For example, a NOAA-led study showed that: 70% of habitat types; 82% of birds, invertebrates, and algal ecosystems; 71% of fish, mammals, and turtles; and 87% of important ecosystem processes were represented in the US MPA network, although no information was provided on the spatial extent of the protection of these features (Brock 2015). The same assessment showed that only two out of 19 marine ecoregions in the US had >1% of their geographic extent within no-take MPAs. In addition, protection gaps have been highlighted in the distribution of MPAs in US waters, with ecoregions close to mainland US benefitting from limited protection, and a great part of the US MPA estate being supported by large MPAs around Pacific Islands (Jessen et al. 2017).

In 1999 the State of California passed the Marine Life Protection Act, a legislation that mandated a list of conservation goals for planning an MPA network. These objectives included the protection of biodiversity and the structure and functions of Californian ecosystems, the recovery of depleted marine resources, and the improvement of educational, recreational, and scientific value of marine ecosystems. Between 2004 and 2011, a science-driven process (Saarman et al. 2013) guided consultations that included bottom-up and top-down participation, resulting in a network of 124 MPAs protecting 16% of California's state waters (within 3 nautical miles from the coastline and the islands, Gleason et al. 2013). In the process, scientists evaluated stakeholder's proposals for MPA networks in terms of habitat representation and replication, to ensure adequate representation of all habitats, species, and ecosystem components, and of MPA size and spacing, to ensure population viability and connectivity (Saarman et al. 2013).

7. Progress towards meeting coverage targets: reported percentages and actual protection

Parties to the CBD are asked to report their protected area coverage (both terrestrial and marine) in their National Reports to the CBD, to track progress against Aichi Target 11. In addition, MPA statistics are reported in a number of other forums, supported and curated by different entities, including: intergovernmental organisations like the United Nations Environment World Conservation Monitoring Centre (UNEP –

WCMC, the World Database on Protected Areas[20]) and the Organisation for Economic Co-operation and Development[21]; governmental organisations within individual countries (e.g. the Collaborative Australian Protected Area Database[22], the UK MPA Mapper[23], and the US MPA Inventory[24]); and non-government organisations (NGOs), like the US-based Marine Conservation Institute (the Atlas of Marine Protection[25]).

Different forums may recognise different standards of protection and implementation for MPAs. As a result, global and national estimates of MPA coverage from different sources may vary. For example, the World Database on Protected Areas (WDPA) is an internationally-mandated global dataset on protected areas compiled and supported by the UNEP – WCMC and IUCN. Data on protected areas included in WDPA need to comply with quality standards and are scrutinized before inclusion, but ultimately data are provided by national (or local) bodies within individual countries (governmental or non-governmental). The Atlas of Marine Protection (MPAtlas, mpatlas.org) is a database of MPAs curated by the Marine Conservation Institute (a US-based NGO). MPAtlas is based on WDPA data, but third-party research identifies which of the MPAs reported to WDPA are implemented. To this end, MPAtlas adopts the definition of "implemented" used by the MPA Guide (Oregon State University 2019), which reads: "*An MPA transitions from existence on paper to being operational on the water, with concomitant management in place that aims to ensure compliance and enforcement. The MPA has a defined boundary, objectives and management strategy that reflect the primacy of conservation objectives (as per the IUCN definition of an MPA)*". As a result, estimates of the extent of MPA networks reported by MPAtlas are often lower than those reported by WDPA. For example, as of May 2020, global MPA coverage is reported at 7.43% of the oceans by WDPA, and at 5.3% by MPAtlas. There are arguments for using each of these sources, depending on the focus of the analysis (Thomas et al. 2014). While discussing such arguments is beyond the scope of this report, it is important to be aware of the differences between different popular sources of data on marine protection (Johnson et al. 2019).

[20] https://www.protectedplanet.net/
[21] https://stats.oecd.org/index.aspx?r=309287#
[22] https://www.environment.gov.au/land/nrs/science/capad
[23] https://jncc.gov.uk/our-work/marine-protected-area-mapper/
[24] https://marineprotectedareas.noaa.gov/dataanalysis/mpainventory/
[25] http://www.mpatlas.org/

A number of recent studies have evaluated global and national progress against international targets based on different sources of MPA data (e.g. Thomas et al. 2014, Shugar-Schmidt et al. 2015, Sala et al. 2018, Gannon et al. 2019, Johnson et al. 2019). As a result, estimates of marine protection vary between scientific studies, too. For example, Gannon et al. (2019) reported that, based on the WDPA as of September 2019, "*Marine protected area coverage for the global ocean was 7.8 per cent*", and that "*Coverage elements are on track to be met by 2020*". However, Sala et al. (2018) argued that the global estate of protected areas reported by the WDPA is inflated and does not correspond to actual protection, because the WDPA includes protected areas at different stages of the implementation process, and estimated the global coverage of fully implemented MPAs as 3.6% of the oceans as of January 2018.

In this section, we provide an overview of the progress towards meeting MPA coverage targets in New Zealand and the countries provided as examples in Section 6 of the present report. For each country, we include the official MPA coverage reported by national governments in the respective Sixth National Report to the CBD. In addition, because the Sixth National Reports cover the 2014 – 2018 period, we also report MPA coverage from WDPA as of May 2020.

Reported percentages of MPA coverage are useful to track countries' progress towards meeting the area-based component of Aichi Target 11, but are not always an appropriate indicator for effective marine protection. To better evaluate countries' progress towards meeting the qualitative aspects of Aichi Target 11, with particular attention to representativeness, we provide examples of potential shortcomings in these countries' MPA networks, in the context of domestic MPA policy. We conducted Scopus searches containing the words "Marine Protected Area", "Targets", and "Objectives", followed by each country's name. We ordered the results from the most recently published and retained papers that provided broad overviews of each country's progress against conservation goals. A systematic review of paradigms for MPA management across countries was beyond the scope of this report.

7.1. New Zealand

In its Sixth National Report to the CBD (Department of Conservation 2019), New Zealand outlined that it had made "*Progress towards target but at insufficient rate*" relative to national Target 13[26] as of April 2018. In particular, it was reported that despite the establishment of new MPAs (including Type 1 MPAs along the West Coast of the South Island and the Subantarctic Island, and Type 2 MPAs on the East Coast of the South Island) and the release of a public consultation document on the proposed reform of MPA management (Ministry for the Environment 2016) during the 2014 – 2018 reporting period, there were still representation gaps in New Zealand's MPA system.

Regarding national progress towards meeting the area-based component of Aichi Target 11, New Zealand reported that, as of 2018: 0.4% of its marine and coastal areas was protected within no-take marine reserves; 0.7% of marine and coastal areas was in Marine Mammal Sanctuaries; 0.1% of marine and coastal areas was in Type 2 MPAs (where bottom trawling, Danish seining, and dredging are prohibited); 27.4% of marine and coastal areas was under some protection of the benthic environment from fishing impacts; and 2.6% of marine and coastal areas was seamounts protected from bottom trawling (Department of Conservation 2019). Therefore, a total of over 30% of New Zealand's coastal and marine areas was under some form of protection as of April 2018, although most of these areas were not Type 1 or Type 2 MPAs (see Section 6.1 of this report). In New Zealand's Sixth National Report it was indicated that the protection of New Zealand's 14 marine biogeographic regions (Ministry of Fisheries and Department of Conservation 2008) is not even, and that 96.5% of New Zealand's marine reserves are located around offshore islands in the far North (Kermadec Islands) or South (Subantarctic Islands), as identified in previous gap analyses (Department of Conservation and Ministry of Fisheries 2011). As of May 2020, WDPA reports that 30.42% of New Zealand's marine area is under some form of protection[27].

Protection gaps in the New Zealand MPA network are in part a result of the main legislation used to establish marine reserves, the Marine Reserves Act 1971 (the Act). One limitation of the Act is that it states that the main purpose for the establishment of marine reserves is "*the scientific study of marine life*"[28]. The Act does provide guidance

[26] Target 13. A growing nationwide network of marine protected areas, representing more of New Zealand's marine ecosystems. Department of Conservation (2016).
[27] UNEP-WCMC (2020). Protected Area Profile for New Zealand from the World Database of Protected Areas, May 2020. Available at: www.protectedplanet.net
[28] The Act has the "purpose of preserving, as marine reserves for the scientific study of marine life, areas of New Zealand that contain underwater scenery, natural features, or marine life, of such

on which areas are worthy of protection within marine reserves (i.e. "*areas of New Zealand that contain underwater scenery, natural features, or marine life, of such distinctive quality, or so typical, or beautiful, or unique, that their continued preservation is in the national interest*"). However, while there may be overlap between areas that are important for biodiversity and areas described as important by the Act, this formulation does not align with international conservation goals of protecting "*areas of particular importance for biodiversity and ecosystem services*", as specified in the body of Aichi Target 11.

To better align New Zealand MPA policy with international best practice, in 2016 the New Zealand government released a consultation document that proposed a new approach to MPA planning (Ministry for the Environment 2016). This approach was proposed to have a more explicit focus on the protection of biodiversity and for improving the current legislation for designing and managing MPAs but was planned to only apply to New Zealand's territorial sea. Unless a revision to the Marine Reserves Act 1971 includes the ability to establish MPAs within New Zealand's EEZ as well as its territorial sea (which only accounts for 4% of New Zealand's total marine estate), then *ad hoc* legislation will be required to increase protection within New Zealand's EEZ (Ministry for the Environment 2016). As of June 2020, the reform of MPA legislation in New Zealand is ongoing.

7.2. Australia

As of 2018, Australia had developed a National Representative System of MPAs that included 314 marine parks, protecting around 3.3. million square kilometres, or 36.7% of Australia's coastal and marine areas (Government of Australia 2020). Official national MPA coverage in Australia is calculated under the Collaborative Australian Protected Area Database (CAPAD[29]), which tracks progress every two years and is maintained by the Australian Government. CAPAD provides protected area information to WDPA (both terrestrial and marine), for the purpose of tracking national

distinctive quality, or so typical, or beautiful, or unique, that their continued preservation is in the national interest". http://www.legislation.govt.nz/act/public/1971/0015/latest/DLM397838.html

[29] https://www.environment.gov.au/land/nrs/science/capad

progress towards the development of protected area networks. According to WDPA, 40.84% of Australia's marine area is under some form of protection[30].

Marine protection in Australia has developed substantially after 2010, and Australia has today a complex network of MPAs organised in zoned and non-zoned MPAs (reviewed in Fitzsimons and Wescott 2018). Zoned MPAs are typically large areas that contain multiple subdivisions allowing different uses and providing different standards of protection. The Great Barrier Reef Marine Park (GBRMP), rezoned in 2004, is one such zoned MPA. The implementation of the GBRMP in 2004 was the result of an internationally-recognised example of successful marine conservation planning, and was one of the first MPAs in the world to be planned with a science-based systematic conservation planning approach (McCook et al. 2010). Non-zoned MPAs are typically smaller areas that offer the same standard of protection across their extent.

While Australia is a country with one of the largest MPA estates in the world, Australia's MPA network was shown to also suffer from protection gaps by unevenly representing Australia's marine bioregions (Barr and Possingham 2013). In addition, Australian MPAs were found to offer no-take protection preferentially to deeper areas that are further from the coast, suggesting that the Australian MPA network is partly residual (Devillers et al. 2015). Finally, review processes reduced the extent of highly protected marine reserves in Australia from 36% of Australia's coastal and marine areas to 33% in 2015, and then down to 20% in 2017. Fitzsimons and Wescott (2018) reported that no public consultation nor scientific analysis were presented to justify the process of reducing the extent of Australia's highly protected marine reserves.

7.3. Canada

In its Sixth National Report to the CBD (Environment and Climate Change Canada 2018), Canada recognised 7.7% of its marine territory as conserved[31], and stated that the 10% area-based component of Aichi Target 11 was on track to be achieved by 2020. More recently, the Canadian Government estimated that Canada had met and

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[30] UNEP-WCMC (2020). Protected Area Profile for Australia from the World Database of Protected Areas, May 2020. Available at: www.protectedplanet.net

[31] In the definition of the Government of Canada (https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/conserved-areas.html): Conserved areas include protected areas, as well as areas conserved with other measures (areas that do not meet the formal definition of protected area but are managed in a way that biodiversity is conserved). Both protected areas and areas conserved with other measures contribute to Canada's conservation network.

surpassed the 10% target after establishing the Tuvaijuittuq MPA[32], with MPAs and other conservation tools protecting collectively around 14% of Canada's marine and coastal areas[33]. In reporting these figures, Canada counted towards its MPA estate conserved areas that do not meet the standard of protection required to be classified as MPAs. Because WDPA only includes areas that meet minimum standards of protection, WDPA reports a coverage of protected areas in Canada's marine estate of only 3.13% as of May 2020[34].

Recent literature reported substantial progress from Canada against Aichi Target 11 from 2015, when total MPA coverage in Canada's marine estate was around 1% (Schram et al. 2019). However, while Schram et al. (2019) reported that Canada protects 8.27% of its total marine estate (before the establishment of the Tuvaijuittuq MPA), the standards of protection of Canada's MPAs have been questioned (Lemieux et al. 2019). Recent progress of Canada towards Aichi Target 11 has been aided by changes in MPA legislation that have allowed Canadian jurisdictions to recognise fishery closures as OECMs. Fishery closures are areas where some types of commercial fishing are prohibited, with the goal of preserving selected fishery resources. Therefore, the primary goal for establishing these areas may often be one of fishery management, rather than of protecting biodiversity. For marine sites to be recognised as OECMs in Canada, a set of criteria is applied, which include conservation or stock management objectives and effective conservation of ecological components of interest (Schram et al. 2019), as indicated by international guidelines (IUCN 2018). However, some scientists have expressed the concern that Canada's OECMs rarely meet minimum standards of protection to be considered effective conservation measures (Lemieux et al. 2019).

Until recently, many Canada's MPAs have offered limited protection (Robb et al. 2015, Lemieux et al. 2019, Schram et al. 2019). In 2008, Canada had designated 161 MPAs, 95 of which were listed as IUCN Type Ia, Ib, and II MPAs (which should offer protection from fishing), but only a minority of those included explicit fishing limitations in their management plans, and 160 of 161 MPAs nationwide allowed some kind of commercial harvesting (Robb et al. 2011). Jessen et al. (2017) estimated the total

[32] https://www.dfo-mpo.gc.ca/oceans/mpa-zpm/tuvaijuittuq/index-eng.html
[33] https://www.dfo-mpo.gc.ca/oceans/conservation/achievement-realisations/index-eng.html
[34] UNEP-WCMC (2020). Protected Area Profile for Canada from the World Database of Protected Areas, May 2020. Available at: www.protectedplanet.net

coverage of implemented MPAs in Canada as 0.11% of the country's marine estate. However, approaching 2020 and with the SPB 2011–2020 expiring, Canada has improved protection over its MPAs by announcing in April 2019 a full ban on all industrial activities in its territorial MPAs, including mining, oil and gas activities, bottom trawling, and dumping (Devillers et al. 2019).

7.4. United Kingdom

As of November 2018, the UK reported in its Sixth National Report to the CBD 314 MPAs covering around 24% of the UK's coastal and marine areas in UK mainland waters (i.e. excluding Oversea Territories) (JNCC 2019). More recent figures from the UK Government reported 25% MPA coverage in UK waters as of June 2019[35], and WDPA reports it at 29.17% as of May 2020[36].

While the UK has 24% of its coastal and marine areas protected in MPAs, extractive activities are allowed in many of these (Sala et al. 2018, Johnson et al. 2019). In addition, although the UK's Sixth National Report to the CBD stated that MPAs in UK mainland waters represent all marine bioregions of the UK in >10% coverage (JNCC 2019), gaps have been identified in the coverage and the ecological coherence of the UK's MPA network. For example, Foster et al. (2014) found that about 10% of English waters in the English Channel are within MPAs, but that the network does not protect all habitats equally. Similarly, as of 2017, the Celtic Sea was also 10% protected within MPAs, but habitat protection was heterogeneous, and connectivity was not guaranteed throughout the network (Foster et al. 2017).

Recent reports highlighted that <20 km^2 is regarded as no-take in UK waters excluding the UK's Overseas Territories (Johnson et al. 2019). However, other than its domestic EEZ around the British Isles, the UK also has jurisdiction over 14 overseas territories that make up 2% of the world's oceans. These include the Pitcairn Islands (>800,000 km^2) in the Pacific Ocean. The UK is in the process of establishing strictly no-take LSMPAs over its 14 territories, and it has designated areas entirely closed to fisheries in the Chagos Archipelago and the Pitcairn Islands (O'Leary et al. 2019).

[35] https://jncc.gov.uk/our-work/uk-marine-protected-area-network-statistics/

[36] UNEP-WCMC (2020). Protected Area Profile for United Kingdom of Great Britain and Northern Ireland from the World Database of Protected Areas, May 2020. Available at: www.protectedplanet.net

7.5. United States

In its most recent government-published report of MPA statistics, the US outlined that more than 1,200 MPAs covered around 26% of US waters, with 96% of this MPA area located around islands in the Pacific Ocean (NMPAC – NOAA 2017). Consistent with these official figures, independent assessments showed that the coverage of MPAs and no-take marine reserves in waters around the continental US is low, and that the Papahānaumokuākea Marine National Monument (Hawaii) contributes the most to the extent of no-take MPAs in the US. The WDPA calculates MPA coverage in the US as of 19.16% in May 2020[37].

Beyond state jurisdiction, national standards for protection and guidelines for the implementation, management, and monitoring of MPAs are present in the US (NMPAC – NOAA 2015). Importantly, in evaluating progress towards meeting conservation targets, the US has adopted the IUCN definition of protected areas[38], and only MPAs aimed at protecting natural and cultural heritage are reported by the US in official forums like the US MPA Inventory.

8. Conclusions

Area-based quantitative targets for marine protection expressed as MPA percentage coverage present a number of shortfalls that have been extensively discussed in the scientific literature. However, area-based (or coverage) targets are easily measurable and interpretable by policy makers and the public, and have a recognised value in the scientific community. As New Zealand undertakes reform of its MPA legislation, and as the end of the Strategic Plan for Biodiversity 2011 – 2020 approaches, extensive scientific evidence from the last 25 years has shown that the widely adopted target of protecting 10% of marine and coastal areas is insufficient to achieve most conservation goals. O'Leary et al. (2016) showed that >30% of MPA coverage is required to achieve most conservation objectives. In agreement with these results, our review of the evidence-based MPA coverage targets published in the period 2016 – March 2020 showed that 21–30% MPA coverage achieved conservation objectives

[37] UNEP-WCMC (2020). Protected Area Profile for United States of America from the World Database of Protected Areas, May 2020. Available at: www.protectedplanet.net
[38] A clearly defined geographical space, recognised, dedicated, and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values. https://www.iucn.org/theme/protected-areas/about

about one third of the time, and that >30% was necessary to meet almost half of the conservation objectives included in our review.

Our results indicate that coverage targets should depend on the specific conservation objectives they are meant to achieve, and are likely to vary depending on the specific ecological and socioeconomic contexts within which they are being applied. The process of setting future conservation targets that are relevant to New Zealand should begin with defining clear conservation objectives within a broader scientific process. For example, information on the movement patterns and dispersal ranges of New Zealand marine animals should be used to inform the requirements of a network of "*well-connected*" MPAs. Once conservation objectives, like ensuring connectivity, are defined, New Zealand may evaluate the effectiveness of different coverage targets in achieving the objectives using systematic conservation planning tools. While the results of our review (as well as previous studies cited in the present report) suggested that no single value of MPA coverage should be adopted *a priori* as a conservation target, a 10% target almost always failed at ensuring connectivity in the MPA network. Consideration of New Zealand's ecological features and processes should help inform setting effective domestic targets.

The countries we considered here (New Zealand, Australia, Canada, UK, and US) have employed scientific methods to evaluate the effectiveness of coverage targets in representing species and habitats. These methods included the use of species-area curves (UK, Rondinini 2010) and of systematic conservation planning (Canada, DFO 2013; New Zealand, Leathwick et al. 2006). In addition, continued environmental monitoring and scientific assessment of the state of the environment have been guiding the process of reviewing conservation targets in the countries we considered here (e.g. Cresswell and Murphy 2017 for Australia, and DEFRA 2012, 2019 for the UK). Future conservation targets in New Zealand should be periodically reviewed, and adapted to meet conservation needs as appropriate. This may be achieved by using decision support tools. Previous studies considering the overlap of New Zealand's MPAs with ecological features like the distribution of demersal fish species (Leathwick et al. 2008), and benthic communities, demersal fish species, and inshore reef fish species (Geange et al. 2017), showed that the use of decision support tools can significantly improve the protection afforded by MPA networks, compared to MPA systems of the same geographic extent designed with more qualitative approaches (such as expert opinion).

The governments of the five countries we considered in this review have all reported on official forums that they have met, as of 2020, the area-based component of Aichi Target 11. However, protection gaps have been identified in the MPA networks of these countries by both government-commissioned and independent assessments. For this reason, it is important that future targets for marine protection in New Zealand include qualitative attributes, including the indication of which ecological features the targets should be applied to. While the concepts of (for example) representativeness, replication, viability, and connectivity all feature in the MPA policies of the countries we considered here, the protection gaps in national MPA networks show that past MPA planning has not always successfully applied these principles. It has been shown that New Zealand's MPA network is not representative of all New Zealand's marine bioregions and benthic habitats in the territorial sea (Department of Conservation and Ministry of Fisheries 2011), and future MPA planning processes have the opportunity to address these gaps to deliver a more effective MPA network.

As the international community establishes post-2020 conservation targets, the scientific consensus is that a higher proportion of the seas needs to be protected, with common estimates around 30–50%. Importantly, area-based targets alone are unlikely to meet future conservation goals, and the quality of protection will have to be evaluated with an evidence-based process geared towards the persistence of species, ecological functions, ecosystem services, and towards the mitigation of climate change.

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Appendix 1. Scopus search string

Search string used to retrieve papers for the review of Section 4.2, as provided by O'Leary et al. (2016). Search was conducted in Scopus' "Advanced search" and only searched titles, abstracts, and keywords of listed publications.

("marine reserve*" OR "marine protected area*" OR marine AND "no take") AND proportion OR model* OR (model* AND fish* OR biomass OR *diversity OR network* OR species) OR (fish* AND conserv* OR yield OR larva*) OR optim* OR selection OR sex* OR design OR connect* OR maximi* or minimi* OR (population AND persist*) OR (network AND size OR systematic* conserv* plan*) OR (*economic AND optim*)

Appendix 2. Studies on MPA targets from 2016 – 2020

Table A2. The 23 studies included in the review of the evidence-based MPA coverage targets (2016 – 2020).

Study	Location	Conservation goals	Methods	Objective	Target (MPA % coverage)	Ranges and nuances
Briggs (2016)	US	Recovery of large predators and fish stocks in San Francisco Bay.	Review / application of heuristic principles	Avoid collapse	50	
Chollet et al. (2017)	Honduras	Avoid population collapse and maximising yield of lobster fisheries.	Systematic conservation planning (spatially explicit population model)	Avoid collapse	20	They model 0–100% MPA coverage and see the effects at 10% increases on persistence of lobsters and fishery yield. 20% is indicated as enough for the stock to never collapse. However, this is dependent on fishing pressure on the unprotected area.
				Fisheries value	20	
Davidson and Dulvy (2017)	Global	Protect 100% of the extent of occurrence of 99 imperilled endemic chondrichthyans	Systematic conservation planning (Marxan)	Protect biodiversity	13	They offer other alternatives based on lower conservation goals. "*Alternatively, we found that protecting half of the EOO for each of the 99 species would only require expanding the MPA network to 3% of the global ice-free EEZ areas—well within the 2020 10% CBD target*".
Davies et al. (2016)	Australia	Protect biodiversity features and zones, and ensuring resilience, while keeping current MPA	Systematic conservation planning (Marxan)	Protect biodiversity	45.8	They also provide MPA coverage required to meet conservation targets if existing MPAs were ignored and the network was designed from scratch. This generally

Study	Location	Conservation goals	Methods	Objective	Target (MPA % coverage)	Ranges and nuances
		network and expanding on it				resulted in lower required MPA coverage than the values needed to meet conservation goals by expanding the existing MPA network.
				Resistance to climate change	41	
				Multiple objectives	53	
Davis et al. (2017)	Australia	Protect 80% of fish and molluscs distribution based on species-area relationships	Species-area relationships and spatial conservation planning (Marxan)	Protect biodiversity	23.5	They use several species-area curves, which give variable results of MPA coverage. Presented values are means as reported by the authors.
				Protect biodiversity	16	
Drira et al. (2019)	Mediterranean	Protect 80% of the fish species within each habitat	Species-area relationships and spatial conservation planning (Marxan)	Protect biodiversity	38	They use several species-area curves, which give variable results of MPA coverage. Mean MPA coverage across habitats for each formulation ranged between 25–60% approximately. Presented values are means as reported by the authors.
Krueck et al. (2019)	Indonesia	Rebuild biomass to increase catches, satisfy stakeholders	Systematic conservation planning (Marxan)	Fisheries value	50	They also report MPA coverage derived from public consultation of local communities (~10%, not based on scientific evidence).
				Multiple stakeholders	16	
Krueck et al. (2017)	Theoretical	Protect biodiversity and maximise (or not affect) fishery yield	Range of modelling approaches	Protect biodiversity	25	They emphasise that MPA coverage required to sustain biomass and fishery yield depends largely on larval export outside of reserves, reserve size, and movement range of fishes. In the light of

Study	Location	Conservation goals	Methods	Objective	Target (MPA % coverage)	Ranges and nuances
						this, they also consider other values of MPA coverage, as high as 50% if reserve size is too small for the movement range of adult fishes and fish spill-over outside the reserve is of 60–100%.
				Fisheries value	25	
Magris et al. (2017)	Brazil	Protect: 10–30% of ecosystem types, spatial extent of functional groups, endemic and threatened species; ensure connectivity; and protect habitat types that can offer refugia from global warming	Systematic conservation planning (Marxan)	Protect biodiversity	90	They also present values of MPA coverage that achieve the conservation goals if the MPA network was designed from scratch. These are generally lower than values of MPA coverage resulting from expansion of the existing network, but still 60–70% of total coral reef area if all objectives are to be achieved.
				Ensure connectivity	80	
				Resistance to climate change	75	
				Multiple objectives	95	
Mann et al. (2016)	South Africa	Ensure fish connectivity	Evaluation of movement patterns by mark-and-recapture	Ensure connectivity	20.45	
McGowan et al. (2018)	Theoretical	Find the optimal spatial configuration (reserve + managed + open) that ensures a minimum yield, maximises biomass, and minimises management cost	Theoretical model	Fisheries value	25	They test MPA coverage 0–100%, and the optimal value depends on the budget for marine management. For a small budget, establishing no-take reserves is cheaper to implement than managed areas, and therefore a reserve

Study	Location	Conservation goals	Methods	Objective	Target (MPA % coverage)	Ranges and nuances
						size of 100% limits the costs and maximises the biomass, but there is no catch.
				Protect biodiversity	60	
Munguia-Vega et al. (2018)	Gulf of California	Guidelines provided to "enhance fisheries, conserve biodiversity and adapt to climate change in the GOC". Multi-approach design.	Review / application of heuristic principles / spatial conservation planning (Marxan)	Protect biodiversity	30	They suggest that MPA coverage of 10% may be used as a target in the future if fishery management outside the reserves improves.
				Fisheries value	30	
				Resistance to climate change	30	
Ovando et al. (2016)	Theoretical	Maximise long-term fishery yield, minimise short-term costs	Numerical model	Fisheries value	25	They test a broad range of MPA coverage and its effects on biomass, fishery yield, and costs, and highlight- that "*While reserves covering 20–30% of habitat often maximized long-term yields in our simulations, shrinking reserves with a terminal size >15% were preferable in terms of short-term economic benefits*".
				Multiple stakeholders	15	
Roberts et al. (2020)	Global	Protect biodiversity and limit climate change effects	Review	Protect biodiversity	30	
				Resistance to climate change	30	
Sala et al. (2016)	Medes Islands	Maximise tourism revenue (associated with increase in biomass) and	Socioeconomic model	Multiple stakeholders	100	

Study	Location	Conservation goals	Methods	Objective	Target (MPA % coverage)	Ranges and nuances
		fishermen's' revenue by profiting from tourist access fees				
Sala and Giakoumi (2018)	Global	Protect marine biodiversity	Opinion / review / heuristic principles	Protect biodiversity	40	
Sala and Rechberger (2018)	Global	Protect biodiversity, ecosystem services, and rebuild fisheries	Review / opinion	Protect biodiversity	50	
				Fisheries value	50	
Timonet and Abecasis (2020)	Portugal	Protect 10–30% (variable) of all habitats and threatened species (mammals and seabirds); ensure connectivity; minimise costs for artisanal fisheries, industrial fisheries, and other uses	Systematic conservation planning (Marxan) and Minpatch for connectivity	Multiple objectives	29	They simulate 12 scenarios that vary in their levels of protection (full protection and protection of priority features only, like endangered species), in the predetermined conservation target (10–30% of habitat extension and species distributions), and in the fishing regimes applied (e.g. artisanal fisheries and industrial fisheries).
Vilar et al. (2020)	Brazil	Protect a number of biodiversity features, including ecologically important distributions of seabirds, reptiles, fishes, and mammal species, as well as Brazil's 8 bioregions. All while minimizing the displacement of commercial activities (e.g. fishing and mining).	Systematic conservation planning (Zonation)	Multiple objectives	11	They quantify the extent of biodiversity features that would be protected with the unconstrained closure of the 10% of Brazil's seascape that supports the highest biodiversity. Then, they calculate the extent of MPA coverage required to meet that same level of protection while also accounting for extractive activities, keeping their displacement to a minimum. MPA coverage in different

Study	Location	Conservation goals	Methods	Objective	Target (MPA % coverage)	Ranges and nuances
						scenarios ranges from 10.3% to 34%.
Virtanen et al. (2018)	Finland	Protect within number of biodiversity features, including 19 IUCN Red List Ecosystems, 125 species of seaweeds, seagrass, and invertebrates, fish reproduction grounds.	Systematic conservation planning (Zonation)	Protect biodiversity	15	They also present the options of expanding Finland's MPA estate from 10% to 11% and 13% of Finland's territorial sea and EEZ, but ultimately 15% is indicated as the value that best meets the objective of protecting biodiversity.
Waldie et al. (2016)	Papua New Guinea	Protect 30–50% of the spawning population of a grouper throughout the non-spawning season	Tagging, acoustic surveys, interviews of fishermen for their perception of existing and proposed MPAs	Avoid collapse	9.38	They consider other MPA sizes to protect the fish population, as high as 100%, but higher sizes than the one proposed are likely to be socially unviable.
Wallmo and Kosaka (2017)	USA West Coast	Maximise household welfare	Socioeconomic model and questionnaire to West Coast US households	Multiple stakeholders	15.6	
Wilson (2016)	Global	Protect 85% of the world's species	Species-area relationships	Protect biodiversity	50	