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Evaluating official marine protected area coverage for Aichi Target 11: appraising the data and methods that define our progress

HANNAH L THOMAS[a,*], BRIAN MACSHARRY[a], LANCE MORGAN[b], NAOMI KINGSTON[a], RUSSELL MOFFITT[b], DAMON STANWELL-SMITH[a] and LOUISA WOOD[a]
[a]*UNEP World Conservation Monitoring Centre, Cambridge, UK*
[b]*Marine Conservation Institute, New Suite 210, Seattle, WA, USA*

ABSTRACT

1. The adoption of the Convention on Biological Diversity (CBD) Strategic Plan for Biodiversity, along with the 20 Aichi Targets, is a strong political endorsement for integrating biodiversity strategy across the entire United Nations system. Aichi Targets represent specific, time-bound drivers for governments to safeguard both marine and terrestrial biodiversity.

2. For the marine environment, Aichi Target 11 represents a call to effectively conserve at least 10% of coastal and marine areas by 2020. The core indicator to measure Aichi Target 11 is the extent of protected area coverage, and therefore it is essential that MPA data used to calculate this metric are robust.

3. The World Database on Protected Areas (WDPA) is the authoritative source of data for measuring Aichi Target coverage progress. The WDPA assimilates global protected areas data as officially reported by the UN Member States themselves.

4. Analysis of the WDPA (August 2014) calculated that MPAs now cover approximately 12,300,000 km^2 or 3.41% of the world's ocean. Only 0.59% of the global ocean area (2 163 661 km^2 within 1124 areas) is protected in no-take areas.

5. Only gathering and using State-sanctioned information may affect the accuracy of the WDPA MPA data. However, it is essential to first and foremost recognize national sovereignty and the rights of the Member State data providers in order to maintain a comprehensive approach to data gathering while ensuring international support for the resulting coverage figures that are used to measure global environmental targets.

6. Further improvements could be made to the MPA data, for example by refining current MPA attributes and working with Member States and conventions to reduce or remove point data in the system. Moreover, broadening the scope of the WDPA to allow the inclusion of clearly marked non-State-sanctioned sites would complement existing official data and facilitate dialogue between Member States and other data providers towards MPA data improvement.

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*Correspondence to: H.L Thomas, UNEP World Conservation Monitoring Centre, 219 Huntingdon Road, Cambridge, CB3 0DL, UK.
Email: Hannah.thomas@unep-wcmc.org

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INTRODUCTION

Our awareness of declines in biodiversity has increased in recent years, along with a better understanding of the implications of such declines, and the need for better integration of biodiversity in broader economic and political processes (Butchart *et al.*, 2010; UN, 2013a). A corollary of this is that global environmental targets, such as the UN Millennium Development Goals and the Convention on Biological Diversity (CBD) Strategic Plan of Action, have become more politically relevant and progressively more specific, measurable, and time-bound over recent decades, which can help to motivate and/or focus action at the national level (Wood *et al.*, 2008).

Aichi Target 11 relates specifically to the effective conservation of marine areas, urging that: 'By 2020, at least 17 per cent of terrestrial and inland water areas, 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' (CBD, 2011). Aichi Target 11 represents a broader, more ambitious marine conservation aspiration than previous global targets but the indicator at the core of the decision is the extent of global protected areas, of which marine protected area (MPA) coverage is an essential component.

The global mandate for gathering protected areas data was conferred upon the International Union for Conservation of Nature (IUCN) and its Conservation Monitoring Centre, now the UNEP World Conservation Monitoring Centre (UNEP-WCMC), by the United Nations General Assembly (UNGA) in 1981. Created as an official inventory to support the UN Official List of Protected Areas (UN, 1962) and now a joint product of the IUCN World Commission on Protected Areas (WCPA) and UNEP-WCMC, the World Database on Protected Areas (WDPA) is a source of protected area boundaries and attributes provided by governments, and including information obtained from NGOs and the published literature (Chape *et al.*, 2005).

The WDPA is considered the most comprehensive source of protected areas data. It has international conservation community endorsement (IUCN, 2003) and is an official, mandated source of data used to calculate global CBD targets (CBD, 2004, 2006; Butchart *et al.*, 2010) and United Nations Millennium Development Goals (UN, 2013b), as well as numerous other global biodiversity and environmental indicators and metrics.

Several earlier publications demonstrate extensive WDPA analysis. Chape *et al.* (2005) described the deficiencies in the WDPA information for protected areas (marine and terrestrial), including boundaries, size, IUCN protected area management categories, and date of designation. They calculated that 0.58% of the ocean was found within protected areas, but underscored the fact that inaccuracies in the spatial and attribute data would produce errors of omission (missing the presence of a species in a protected area) and commission (wrongly identifying a species as present in a protected area), which would limit the ability to correctly identify gaps and priorities for conservation (Chape *et al.*, 2005). These conclusions contributed to a CBD call for improved marine and coastal protected areas data within the WDPA (CBD, 2003) and as a result, a significant number of additional MPA site boundaries and attributes were collected through independent research and direct communication with regional and national experts, resulting in a *c.* 75% change to the original WDPA data (Wood *et al.*, 2008). Using these improved data, the rate of increase of protected area extent since 1985 was plotted and projected into the future, leading Wood *et al.* (2008) to predict that the CBD target to protect 10% of Exclusive Economic Zones (EEZ) by 2010 would not be met before 2047, and the IUCN 2003 World Parks Congress target of 30% protection of the ocean by 2012 might only be reached in 2092.

Spalding *et al.* (2008) used the WDPA MPA layer and the Marine Ecoregions of the World (MEOW) to assess representative protection of the world's ocean, finding that approximately half of all marine ecoregions only had less than 1% protection. The same analysis was undertaken again in 2010, calculating that 1.17% of the global ocean was protected and demonstrating a 60% increase in MPA coverage in the 30 months following the

Spalding *et al.* (2008) analysis (Toropova *et al.*, 2010). Although this remained below the CBD target level, the dramatic increase in coverage was used to challenge the Wood *et al.* (2008) projected time frames for meeting global targets (Toropova *et al.*, 2010). Indeed, Spalding *et al.* (2013) used the WDPA data to reassess progress towards global MPA targets 3 years later, specifically focusing on the newly agreed Aichi Target 11. The increasing rate of protected area coverage (from 1.17% to 2.3% of the global ocean area) led Spalding *et al.* (2013) to conclude that the Aichi Target 11 goal of 10% of MPA coverage by 2020 was achievable.

Although all authors addressed gaps in the WDPA data when undertaking their analyses, the conclusions drawn inevitably rely upon the accuracy of the WDPA MPA dataset and thus the resulting trend in MPA coverage will, in part, be attributable to improvements in the WDPA (Toropova *et al.*, 2010). Recently, Visconti *et al.* (2013) directly addressed the effects of gaps and errors in the WDPA spatial data upon the assessment of conservation progress and found that extremely significant under- and over-estimation of habitat protection was possible depending upon the proportion of the WDPA sites that had missing polygon boundary data or the extent to which Locally Managed Marine Areas (LMMAs) were included in the database. Although Visconti *et al.* (2013) made sensible suggestions as to how to improve these issues, their assessments revealed some misunderstandings around the WDPA data, how they are gathered and therefore how they might be improved. More recently, Cros *et al.* (2014) suggested there was a serious discrepancy between the WDPA and the regional Coral Triangle Atlas as a result of the MPA classification used by the WDPA, which they asserted led to including 'areas with a coastal boundary as an MPA, even if the area is not managed for its marine habitats', a statement that is highly misleading. While there are certainly inaccuracies in the WDPA due to misidentification by data providers of protected areas as marine when they are in fact terrestrial, marine sites should only be submitted to the WDPA if they are 'recognised, dedicated and managed' (Day *et al.*, 2012) for marine features, as described in the WDPA Data Standard. These misunderstandings in the published literature emphasize a need for greater clarification of the WDPA site submission process and the precision of its resulting data holdings. While improvements to the WDPA data are always necessary and are always being made, the official mandate has resulted in a complex data collation and curation approach that inevitably affects the nature of such data and the statistics generated from them, and this is particularly true with regard to global MPA coverage.

Since the WDPA MPA layer forms the basis of extensive and highly significant statistical analysis to assess global conservation progress and priorities, it is essential that the database is as accurate and comprehensive as possible, to provide robust data for global MPA coverage metrics. The aim of this paper is not to undertake extensive conservation progress analyses, as has been done by previous authors and is presented in the 2014 Protected Planet report (UNEP-WCMC in prep.) but is to underscore the importance of maintaining high quality WDPA MPA data and the need for users to understand the WDPA strengths and weaknesses when performing important analyses. As such, areas for WDPA MPA improvement are discussed in order to enhance these evaluations in the future.

The current paper seeks to:

a) highlight the importance of developing a mandated and authoritative database, and describe the responsibilities and limitations involved in maintaining official, comprehensive, well defined and up-to-date MPA data that are the fundamental basis for coverage statistics and other protected area analysis;
b) appraise the methodology for calculating official MPA coverage statistics;
c) present the latest MPA and no-take area coverage statistics and maps; and
d) discuss possible improvements to the WDPA MPA data that could assist with Aichi Target 11 reporting and any MPA-related analysis.

Developing and maintaining an official global database of MPAs

During the 2004 CBD 7th Conference of the Parties, Member States invited UNEP-WCMC to

'further develop the World Database on Protected Areas in order to assist the monitoring of progress towards the overall objective of this decision' and urged 'Parties, other Governments and relevant organizations to provide up-to-date information for the Database' (CBD, 2004). In light of its mandate, the WDPA has a responsibility to adopt a rigorous and consistent approach to assimilating global protected areas data that is supported by the UN Member States themselves. By requesting State-sanctioned data from official government sources as the core of the data holdings, the WDPA data are acceptable to Member States as a way to measure success or failure with regard to meeting global targets.

Obtaining official MPA data

The collection of MPA datasets from the 193 UN Member States follows a specific protocol to ensure that the data received are officially approved by Member State governments. However, due to significant variation between countries in terms of the structure, resourcing, and capacity of government agencies responsible for protected areas, this is typically a complex process that can involve engaging with several country representatives in order to procure a complete, up-to-date dataset. The initial request for updated data is sent to representative Member States and their associated territories, or to NGOs, relevant regional bodies and/or international secretariats such as CBD focal points, IUCN and UNEP regional offices, and IUCN World Commission on Protected Areas members, who may be authorized to act on behalf of the Member States.

With so many data providers to the WDPA, the wider challenge is to ensure the continuous provision of harmonized, comprehensive and up-to-date MPA data. Member States may lack capacity, both in terms of number of staff and technical ability, to manage their protected areas datasets and ensure they remain contemporary. Engaging with Member State data providers to obtain data can also be a lengthy process owing to resourcing, data-sharing and copyright restrictions. Where multiple state bodies are responsible for MPA information within a Member State there may be a lack of standardization between the different bodies such that data formats differ between them. To overcome this problem, UNEP-WCMC produced the WDPA Data Standard, a document outlining the minimum data requirements for protected areas information and aimed at ensuring that data are supplied in a common, harmonized manner, thereby facilitating the integration of data from multiple data providers (UNEP-WCMC, 2014). The process to update the WDPA is an ongoing workflow and, typically, protected area data are updated for around 60 countries each year. The preparation of the 2014 UN Protected Areas List has greatly strengthened this communication channel with national data providers and will help to expedite the incorporation of new designations into the WDPA.

Defining an MPA

There are many definitions for what constitutes an MPA. In 1999, the International Union for Conservation of Nature (IUCN) defined a marine protected area as 'any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment' (Kelleher, 1999). However, in its revised Guidelines for Applying the IUCN Protected Area Management Categories to Marine Protected Areas (Day *et al.*, 2012), IUCN makes no distinction between spatial protection in the marine and terrestrial environments, and defines a 'protected area' as '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'. The IUCN definition describes the benchmark for data inclusion within the WDPA, providing flexibility to governments to define which sites they feel are designated to achieve long-term conservation. Given that the WDPA is used to report against CBD targets, it is important to note that there is tacit agreement between IUCN and CBD that the IUCN definition corresponds to the

CBD definition, which is 'a geographically defined area which is designated or regulated and managed to achieve specific conservation objectives' (Lopoukhine and de Sousa Dias, 2012). In practice, such variations in definition will inevitably affect WDPA data submissions, particularly since governments may well be guided by specifically marine and/or coastal biodiversity definitions (CBD, 2004) that may be open to wider interpretation (Spalding *et al.*, 2013). To identify WDPA protected areas as being designated completely or partially for marine elements, the WDPA Data Standard requests that data providers identify sites with a marine attribute if they 'encompass any portion of the marine environment in whole or in part according to a protected area's geographic location and management strategy' (UNEP-WCMC, 2014).

Protected area management objectives

As the global MPA network has expanded, the terminology used to describe MPAs and the range of management objectives, approaches, and restrictions applied within them has also expanded and diversified. In order to try to simplify this growing complexity, IUCN developed the protected area management categories (IUCN/WCMC, 1994; revised Dudley, 2008; Stolton *et al.*, 2013). Six IUCN categories classify areas according to their management objectives, from Strict Nature Reserve (category Ia) to Protected Area with Sustainable Use of Natural Resources (category VI). The WDPA Data Standard requests that protected area data are accompanied by IUCN PA management category information and no-take area information in the form of area (km^2) under no-take management.

METHODS

Assessing MPA coverage

Due to overlapping protected area designations and the need to select out MPAs from amongst all other protected areas, the process of calculating global MPA coverage requires a series of geospatial processing and verification steps that are described below, performed using the August 2014 version of the WDPA (IUCN and UNEP-WCMC, 2014).

Identify and extract MPAs

The WDPA has a specific 'marine' data attribute field to identify MPAs and the WDPA Data Standard requires that data providers record a '1' in this attribute field to flag full or partial MPAs. All other sites that are not marked with '1' are considered to be terrestrial.

Although the marine attribute helps to identify MPAs, it relies upon the data provider to correctly attribute a site as having marine conservation objectives, which can lead to errors occurring in the data where non-marine sites are erroneously labelled as MPAs and true MPAs are not given the marine attribute. Without any other specific attributes to label terrestrial sites or coastal sites that may be designated for both marine and terrestrial features, non-marine sites are identified by default rather than by deliberate labelling, thus reducing the certainty with which sites providing marine, terrestrial or coastal protection can be accurately selected. This is problematic when site boundaries overlap both marine and coastal environments, as the overlap with the marine area may define a real MPA or may simply be a result of spatial errors in site boundary definition, coastline data precision or misaligned Geographical Information System (GIS) projections.

For the purposes of calculating global MPA coverage, we extracted all sites with a marine attribute and then modified those data for analysis, either to include WDPA sites that did not have a marine attribute but were considered to be designated for marine elements, or to remove the marine attribution for terrestrial sites that were obviously not appropriately flagged. This was done by undertaking a series of geo-processing steps, as follows:

a) The complete protected areas dataset (marine and terrestrial sites) was clipped to the shoreline dataset.
b) All protected areas located completely on land (or in freshwater areas with no linkage to the sea) were removed from the dataset, irrespective of whether data providers had attributed them as marine sites.

c) Protected areas located completely within the marine environment (i.e. with no terrestrial overlap) were considered as MPAs, even if they were not tagged with the marine attribute.
d) The clipped marine portion of coastal protected areas (i.e. sites overlapping the coastline) were identified as MPAs if:

   i. more than 100 ha of the site fell in the marine environment;
   ii. more than 10 ha of the site fell in the marine environment and this represented more than 30% of the entire site area itself;
   iii. the site had a marine designation name (i.e. contained the words 'marine'; 'ocean'; 'sea' or 'water') and, upon verification, was considered a valid marine site (i.e. not a freshwater lake);
   iv. subsequent examination did not flag up any geospatial errors.

Adjust for missing boundary data

Although polygon data are requested in the WDPA Data Standard, some data providers submit MPA information in the form of geo-referenced point data with no accompanying boundary information. To calculate coverage statistics, MPA point data are buffered with a circle of area based on the 'reported marine area' values reported by the relevant data provider. In some partly marine sites, however, area data may be reported as generic 'area', in which case, this is used to calculate the buffer.

Remove sites with insufficient spatial or attribute data

Point data without a specific spatial area are not included in the analysis. UNESCO Man and Biosphere (MAB) Reserves Reserves are defined as a core area and a buffer zone, with only the former area corresponding to the IUCN protected area definition. Many MAB Reserves are submitted to the WDPA without associated boundary data, but where this information is provided, data providers often do not indicate the difference between core and buffer areas. Fifty-one per cent of MAB sites are also provided as point data but there is insufficient accompanying information to confirm whether the point would represent the centroid of the core area alone or of both the core and buffer zone together. Due to the low precision of the point data coordinates and reported area figures, the MAB sites are removed from the analyses. Work is ongoing with the UNESCO MAB Secretariat to improve the quality of data provided by national MAB Reserve focal points.

Dissolve all MPA designations together into a single layer

The WDPA holds spatial records for an enormous range of different MPA designations that range from local through regional to national scales, many of which overlap. Calculation of the combined surface area of all these sites would represent a very significant overestimation of marine habitat coverage receiving protection. To overcome this problem, the boundary shapes of all the individual site polygons are 'dissolved' together in a GIS processing exercise. This creates a single 'flat' layer of MPAs where the outermost boundary of any overlapping polygons is retained, thus removing the spatial overlap of MPAs to obtain an accurate representation of MPA coverage. In doing so, all associated attribute data are removed, including IUCN management category and no-take status.

Clip the dissolved data to the shoreline

Since many protected areas have conservation objectives for both terrestrial and marine systems within a single boundary, the marine-attributed data must still be clipped to the relevant shoreline in order to discount the terrestrial area covered. To do this, the National Oceanic and Atmospheric Administration (NOAA) World Vector Shoreline (WVS) (NOAA, 2014) was used. The WVS is considered to be the highest quality, freely available dataset providing the opportunity for the methodology to be replicated.

Calculate extent of MPA coverage according to geopolitical boundaries

Coverage statistics are calculated for Territorial Seas, which extend 12 nautical miles (nm) out from the shoreline; the area of the Economic Exclusion Zone (EEZ 12-200nm) and for Areas Beyond National Jurisdiction (ABNJ). Although most countries have an EEZ that delineates

sovereign waters out to 200 nm from the shoreline, some boundaries remain controversial. In the Mediterranean, for example, some countries have not claimed an EEZ, while others have EEZ (or derivative maritime zone) claims that are either underway or contested by neighbouring countries. Other countries claim the extended continental shelf (out to 300 nm) as within their national jurisdictions. For the official coverage statistics, the Flanders Marine Institute (VLIZ) *Marine Boundaries* (VLIZ, 2014) are used to delineate Territorial Seas and EEZ boundaries. However, the VLIZ layer has been adjusted to remove the EEZ boundary drawn around Antarctica, which is not legally supported under the Antarctic Treaty. Although these boundary data will inevitably be subject to change due to jurisdictional sensitivities, they are regularly updated, and freely available to allow replication of the methodology.

RESULTS

Global MPA numbers and coverage

In total, 17 082 MPAs were identified for this analysis. Because a very large number of these MPAs represent different designations overlapping the same geographical space, the number of MPAs is not a robust metric for measuring global conservation progress. Global MPA coverage is a much stronger indicator and is used to measure the marine element of Aichi Target 11.

A map of the distribution of global MPAs is shown in Figure 1. According to this analysis, MPAs now cover 12,302,271km^2 or 3.41% of the world's ocean. The addition of the New Caledonia MPA, designated in 2014 and incorporated into these WDPA coverage statistics, now represents the largest MPA currently established, and at 1,292,962km^2, is also the largest protected area anywhere in the world.

When looking at the distribution of these MPAs across differing jurisdictional areas, the vast majority of MPAs are located within Territorial Seas (0–12 nm), with 10.92% MPA coverage. For EEZs (12-200nm), 7.99% are covered by MPAs, but this figure drops dramatically in Areas Beyond National Jurisdiction (ABNJ), where the coverage is 0.25%. Figure 2 shows the proportion of all the world's Territorial Seas and EEZs (0–200 nm) that have <1, 1–5, 5–10, 10–30 and >30% MPA coverage, and Figure 3 represents this information

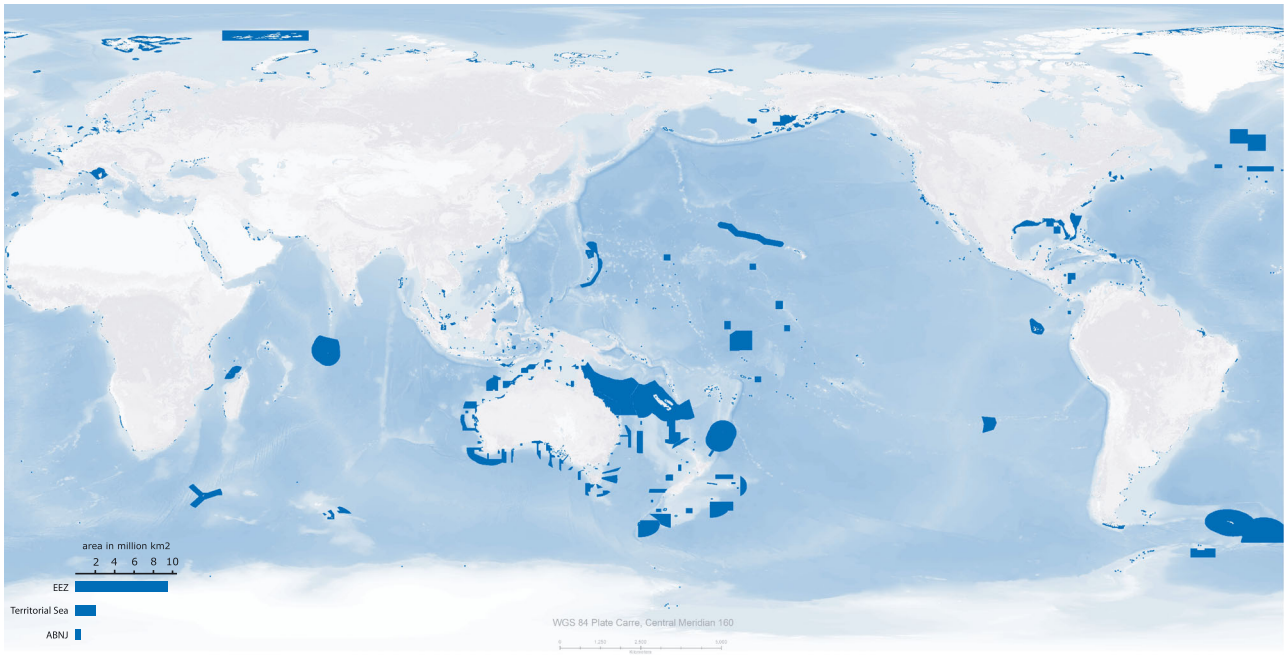

Figure 1. Map showing the distribution of global MPAs covering 3.41% of the ocean. Bar chart (bottom left) shows MPA coverage area (in million km^2) for Territorial Seas (0–12 nm), EEZs (12–200 nm) and ABNJ (>200 nm).

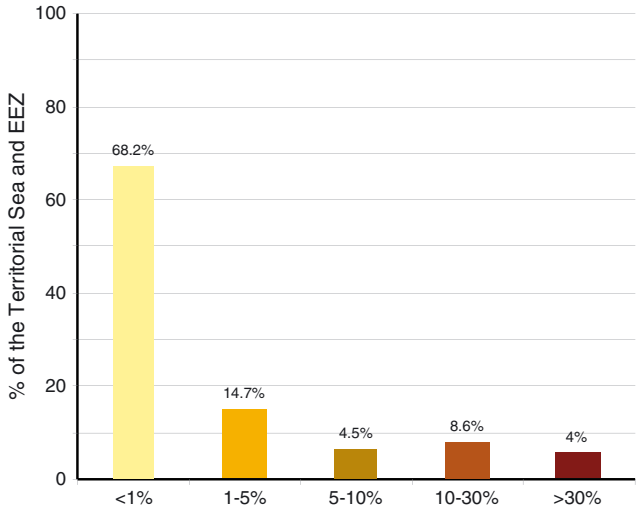

Figure 2. Proportion of the world's Territorial Seas and EEZs that have reached various percentage MPA coverages.

as a colour-coded global map. These figures clearly show that the vast majority of the world's waters covering Territorial Seas and EEZs (87.4%, lightest three colour bins in Figures 2 and 3) have not yet met the 10% Aichi Target 11 aspiration for marine and coastal protection.

Trends in numbers and coverage over time

Figure 4 shows the trend in MPA coverage over time for Territorial Seas (0–12 nm), EEZs (12-200 nm), ABNJ, and the global ocean. MPA coverage within Territorial Seas has steadily increased during the last two decades. By contrast, growth in MPA coverage in areas outside Territorial Seas has remained very slow, climbing less than 1% in the same period until 2002, when a significant upward trend is apparent within national jurisdictions due to several large MPAs being designated in Europe as part of the Natura 2000 network and the comprehensive designation of the Great Barrier Reef as a World Heritage Site. Expansion in MPA coverage has continued in a relatively exponential fashion ever since, with increased coverage occurring between 2009 and 2011 when a large number of extremely large MPAs were designated, including the British Indian Ocean Marine Protected Area (Chagos) MPA, Phoenix Islands Protected Area and Papahānaumokuākea World Heritage Sites, Charlie-Gibbs South High Seas MPA, Motu Motiro Hiva Marine Park, the South Orkney Islands Southern Shelf MPA, the Australian Commonwealth Marine Reserves and the South Georgia & South Sandwich Islands MPA, and the New Caledonia MPA designated in 2014.

The exception to the escalating MPA coverage trend has been in marine ABNJ. In 2002, the Pelagos Sanctuary in the Mediterranean was the first high seas MPA to be established, when the

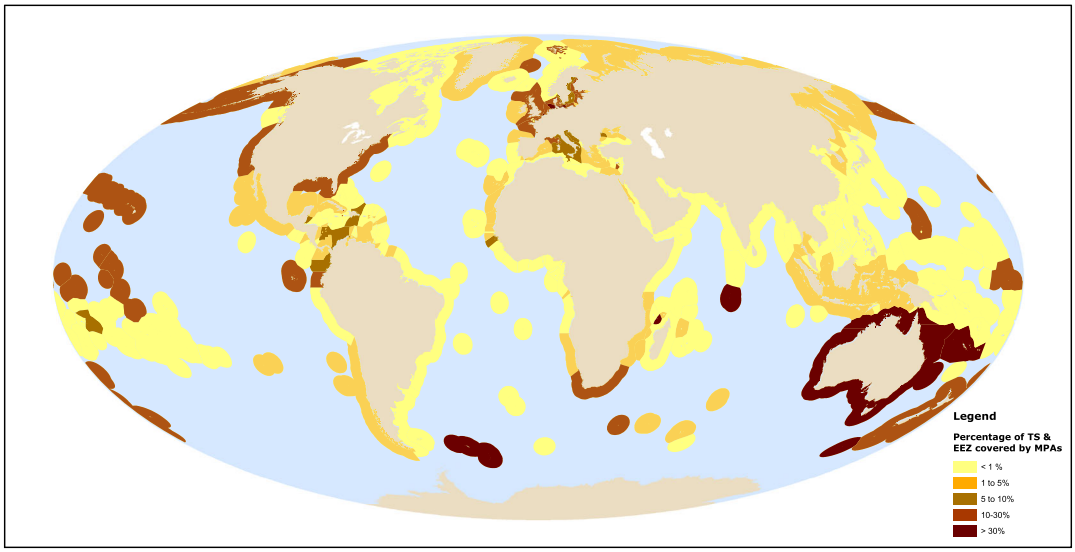

Figure 3. Map of the world's Territorial Seas and EEZs colour-coded by percentage MPA coverage.

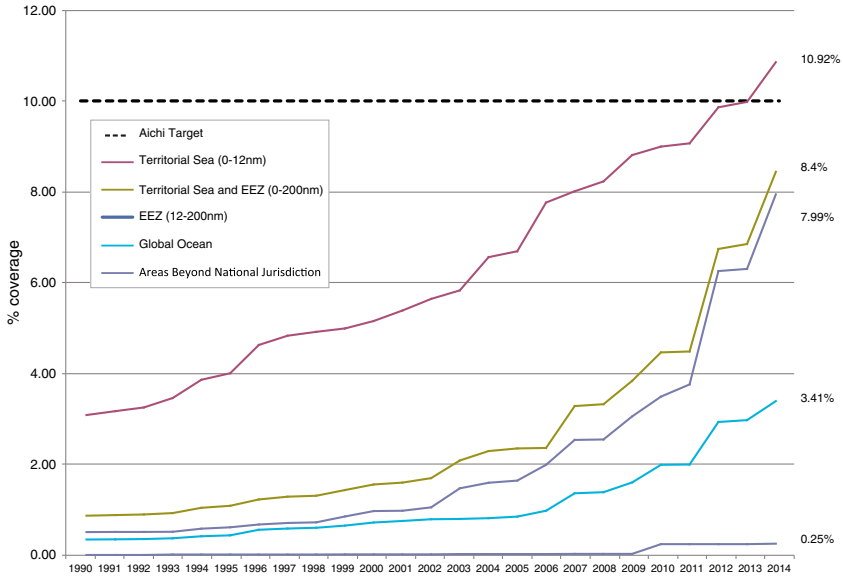

Figure 4. Trend in global MPA coverage over time within Territorial Seas (0–12 nm); Exclusive Economic Zones (EEZs; 12-200 nm); and Areas Beyond National Jurisdiction (ABNJ).

relevant coastal states (France, Italy and Monaco) had not elected to claim an EEZ. Now, however, these coastal states are in the process of establishing their EEZs and derivative zones and the Pelagos Sanctuary falls entirely within such areas of jurisdiction. In 2010, the South Orkney Southern Shelf MPA was established in ABNJ under the Convention for Conservation of Antarctic Marine Living Resources (CCAMLR), which provides the legal framework for MPAs within Antarctic waters. The first network of ABNJ MPAs was established within the OSPAR Regional Seas area. The MPAs in the North-east Atlantic OSPAR region represent an example of how to address the

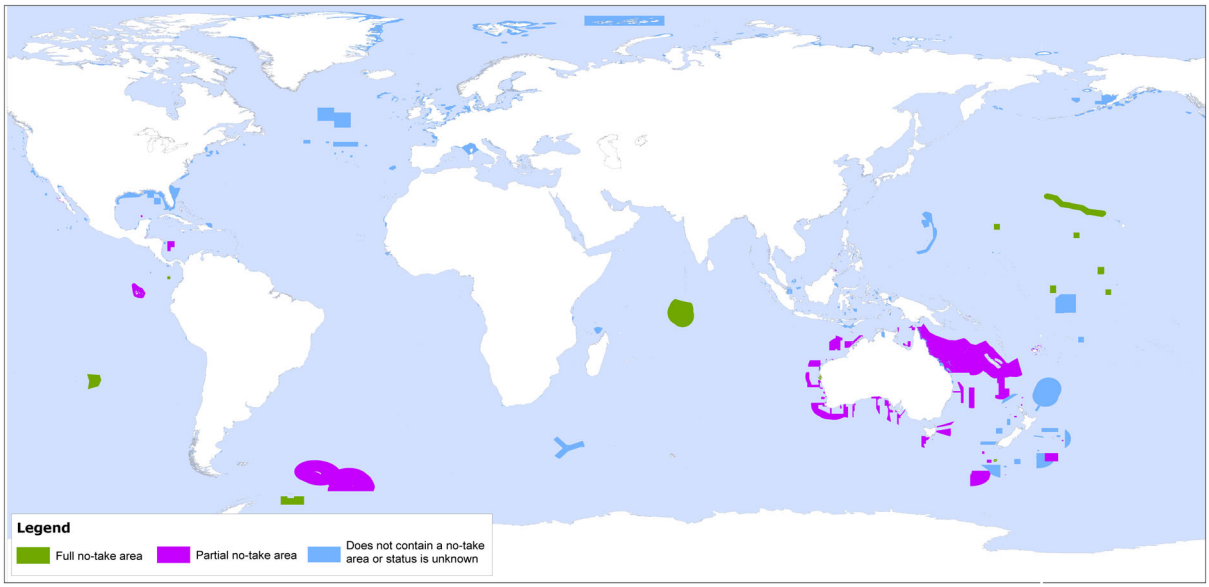

Figure 5. Map of no-take areas and no-take zones within larger multiple-use marine protected areas. Areas in green are full no-take areas. Areas in pink contain no-take zones within the MPA. Areas in blue either do not contain no-take zones or their no-take status is unknown.

significant challenges presented when implementing marine conservation where governance frameworks are weak. Under the legal framework of the UN Law of the Sea (UNCLOS), contracting parties to OSPAR exercised their Regional Seas remit to collectively adopt marine protection measures, but since there is currently no mechanism for creation of MPAs in ABNJ under UNCLOS, comprehensive biodiversity protection was achieved through collaborative agreement between the relevant competent authorities for management of human activities beyond OSPAR's remit, such as fishing, mining, and shipping (O'Leary *et al.*, 2012). This demonstration of multi-sectoral and multi-national spatial planning beyond national jurisdiction will hopefully pave the way for increased MPA coverage in these remote yet vulnerable areas.

No-take zone coverage

Only about 0.59% of the global ocean (2 163 661 km^2 within 1124 sites) is protected in no-take areas or no-take zones within larger multiple-use protected areas (Figure 5).

Based on MPA no-take zone attribute information contained within the WDPA, no-take marine reserves tend to be less than 10 km^2 in size (Figure 6). The median no-take zone size is about 1.7 km^2, while the British Indian Ocean Marine Protected Area (Chagos) is the largest no-take MPA (640 000 km^2) and the third largest MPA of any kind after New Caledonia (1 291 643 km^2 with 0.25% or 3236 km^2 no-take) and the South Georgia & South Sandwich Islands MPA (1 070 000 km^2 with 2% or 20 431 km^2 no-take).

Figure 6. Histogram showing frequency distribution of no-take area size classes.

DISCUSSION

From the last published global MPA coverage figures of 2.3% in 2013 (Spalding *et al.*, 2013), the addition of recent MPAs including the largest MPA yet (New Caledonia MPA) into the WDPA has pushed the global coverage figure to 3.41%, which represents an increase of approximately 4 million km^2. The MPA data in the WDPA are sufficiently robust to enable the calculation of meaningful global MPA and no-take zone coverage trends over time, as the present study and numerous authors demonstrate (Wood *et al.*, 2008; Bertsky *et al.*, 2012; Spalding *et al.*, 2013). Unsurprisingly for a global database, however, there are a number of areas where the quality of the MPA data may well affect the precision of the resulting coverage statistics. These are discussed and ways to improve such areas are considered.

MPA identification

The WDPA contains all forms of protected areas that conform to the IUCN Protected Areas definition. The resulting dataset is likely to contain numerous different interpretations of what constitutes an MPA. For example, there are 131 MPA designations used in US waters, with federally designated MPA types including wildlife refuges, monuments, marine sanctuaries, fisheries closures, habitat areas of particular concern, and estuarine reserves. A similar situation exists in other countries, resulting in a total of 561 different nationally, regionally and globally applied MPA designations submitted to the WDPA. However, some of these designations, such as Locally Managed Marine Area (LMMA), are State-sanctioned as an MPA by some Member States but not others, resulting in their underrepresentation in the WDPA.

Having a specific 'marine attribute' is essential, since it allows data providers to identify protected areas that are designated entirely or partly for

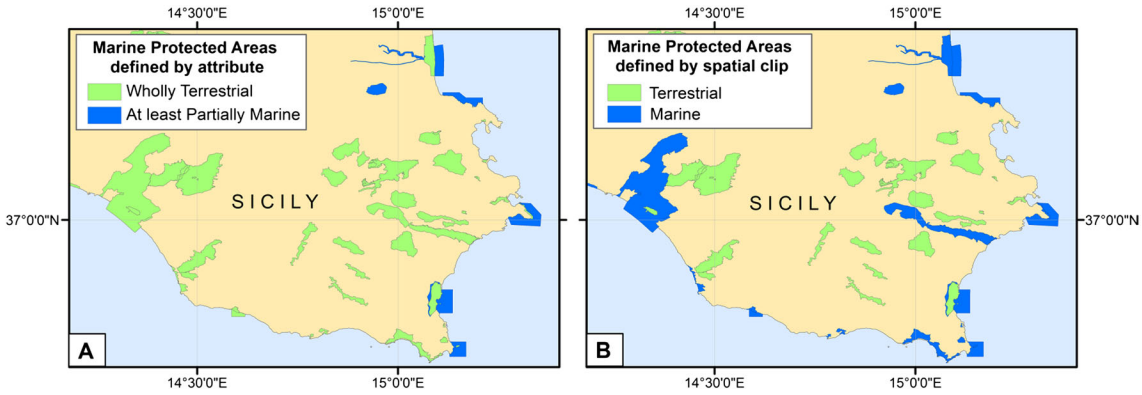

Figure 7. Two maps of the same geographical area of Sicily showing the identification of MPAs that would occur: (A) using the marine attribute in the WDPA; and (B) using a spatial clip with the shoreline.

marine features. Without the marine attribute, a spatial clip of the entire protected areas dataset with a particular coastline would incorrectly select sites that may cover the marine area but have no specific marine management objectives. Similarly, MPAs protecting the upper intertidal areas of mangrove and saltmarsh habitats would often be lost in a spatial clip using global coastlines that do not include this area as marine. Figure 7 is an example of how a different set of MPAs in Sicily could be identified depending on the method used, in this case either through a spatial clipping exercise or through the marine attribute field in the WDPA. In addition, a lower resolution shoreline data layer may result in an overestimate of MPA area in regions that have a particularly fragmented coastline. Figure 8 highlights this point, showing that the MPA coverage figures that are calculated from the same country (Finland) using two shoreline datasets of differing resolutions are 6904 km^2 (1:250,000 resolution) and 7245 km^2 (1:1 000 000 resolution), which would equate to national MPA coverage statistics for the total marine area as being 8.54% and 8.96%, respectively.

In reality, coastal site boundaries that intentionally span both the land and the sea may not necessarily have equivalently comprehensive management objectives for the marine features as for terrestrial ones. Although it is essential to enable correct identification of sites managed for marine features, the marine data attribute is clearly not being applied consistently across data providers, and there are therefore errors in the dataset that mean substantial verification and improvement should be undertaken before any

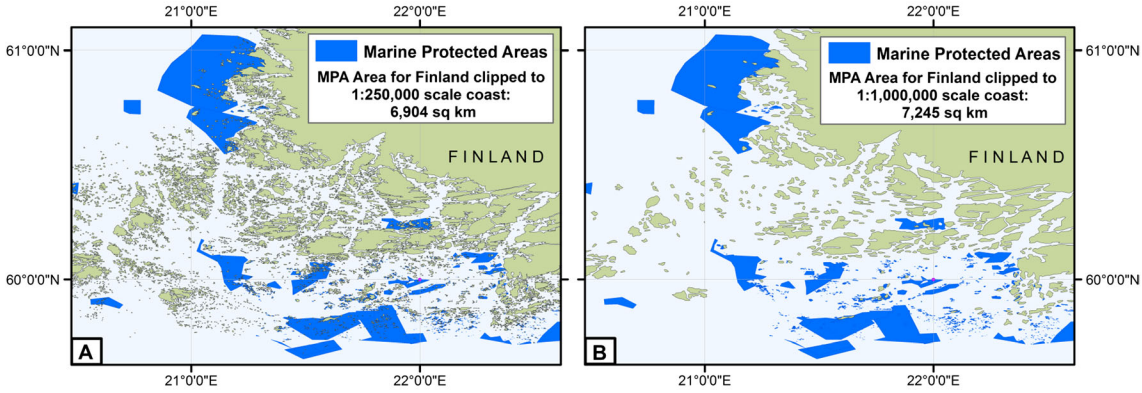

Figure 8. Maps showing how altering the resolution of the shoreline dataset used to identify coastal features or small islands can affect MPA coverage statistics. The coverage for Finland's MPAs in territorial seas is (A) 6904 km^2 when using a high resolution 1:250 000 shoreline; compared with (B) 7245 km^2 when using a lower resolution 1:1 000 000 shoreline.

analysis. Strengthened communication with data providers regarding the definition and attribution of MPAs in marine and coastal areas is clearly a priority for improving WDPA data. However, the marine attribute could be expanded very simply to provide more information about where a protected area is located in order to enable a more refined analysis. For example, a three-category classification based upon management objectives that distinguished: (1) wholly marine MPAs, (2) coastal marine/terrestrial MPAs; and (3) wholly terrestrial PAs would provide greater flexibility for extracting relevant protected areas and identifying potential areas of uncertainty for further investigation. To increase the accuracy of coverage statistics, data providers could be requested to state the proportion of any coastal site that receives protection for marine features, which could then be included in the WDPA as an additional attribute.

Inaccurate or missing boundary data

One of the largest sources of uncertainty in the coverage statistics comes from point data. Of the total WDPA MPAs extracted for this analysis, 671 points are converted to buffered centroids according to their reported (marine or total) areas. These buffered centroids will obviously lose part of their coverage when they are subsequently bisected by the shoreline (stage 5 in the Methods), leading to underestimation in global MPA coverage. Ninety MPA points without any reported area were removed entirely. Most of these points data (n = 76) are not overlapped by other MPA designation boundaries, meaning that they could represent additional MPA coverage, although many have crude latitude and longitude coordinates making their accuracy impossible to gauge.

The most effective solution to this problem is to ensure that all MPAs have polygon data, and this is requested in the WDPA Data Standard. However, in instances where that is not yet possible (e.g. countries that have not yet digitized their MPA boundaries), the most appropriate interim solution is to encourage data providers to report the actual marine area of the site, in accordance with the WDPA Data Standard. This would at least allow a greater understanding of the true coverage.

Errors in area calculations also occur with inaccurate boundary data. Many MPAs on small islands have both marine and terrestrial objectives but are delineated solely by the island's shoreline, with none or very little of the boundary overlapping the marine realm. These protected areas are partial MPAs but due to the very fine resolution of data required to accurately describe the boundary of small islands in relation to the associated MPA boundaries, any spatial geo-processing analysis at global scales will inevitably miss the extent of the marine coverage.

Although some authors suggest that boundary data can be procured or improved upon by unilaterally researching the boundary and adjusting the data (Visconti *et al.*, 2013), this approach is not appropriate in the context of the WDPA with its UN mandate and responsibility to respect the information provided by Member States. Although the WDPA has had significant data input from a wide range of international NGOs such as IUCN, Birdlife International, Conservation International, The Nature Conservancy, and WWF, the current WDPA data are characterized primarily as a multinational collective effort, with Member States as the main data providers of State-sanctioned areas according to their own legal frameworks. The WDPA provides clear baseline definitions and metadata standards for requested data, but gives ultimate responsibility for data accuracy to a wide range of national and international data providers. In order to address these issues in the database, each data point provider must be contacted, either to specifically request boundary data, or to formally approve suggested alternative boundaries. Improving and streamlining engagement and the associated work flow with data providers would certainly assist this process. It could be most effective to trial this approach with international agencies responsible for global MPA designation such as UNESCO, where considerable improvements to the data could be made by strategic organizational partnerships to gather boundary data for numerous data points.

Protected area management objectives

The vast majority of MPAs, both in terms of numbers and area, allow fishing and other extractive activities as well as diving, boating, and other recreational and commercial uses. In contrast more highly protective, no-take areas are few in number. Recent scientific results suggest specific combinations of factors result in strong conservation outcomes, including higher large fish diversity and abundance, for MPAs that have been strongly protected for long enough (>10 years), and are large (>100 km^2) and isolated (Edgar *et al.*, 2014). Increasing evidence shows the ecological benefits of full no-take reserves, and demonstrates that the benefits of other types of MPAs vary by protection levels, such that lesser restrictions on activities show more modest benefits (McClanahan *et al.*, 2007; Lester *et al.*, 2009; Selig and Bruno, 2010). Such evidence confirms the importance of capturing accurate and comprehensive up-to-date IUCN category and no-take zone information within the WDPA.

The IUCN protected area management categories are also recognized by the CBD as integral to defining and measuring protected area effectiveness, a key element of Aichi Target 11 (Lopoukhine and de Sousa Dias, 2012; Woodley *et al.*, 2012). Indeed, CBD decision VII/28 'encourages Parties, other Governments and relevant organizations to assign protected-area management categories to their protected areas, providing information consistent with the refined IUCN categories for reporting purposes' (CBD, 2004). Although IUCN categories are reported for 52% of MPAs, many of these category assignments took place before the newly released guidelines to clarify how to assign the IUCN categories to MPAs (Day *et al.*, 2012). As such, many of the existing classifications are outdated and/or potentially inaccurate (for example, no-take areas have been reported in all IUCN categories).

Specific reporting of no-take area (for the entire site or part of it) is requested in the WDPA Data Standard, along with the associated no-take area in km^2. Nevertheless, this field is not comprehensively completed for known no-take areas by data providers and is open to error. Improved no-take area figures are essential for providing a clear picture of marine and coastal protection levels, a fundamental part of Aichi Target 11. More detailed information on these important sites would be highly valuable for a range of users. Providing no-take boundary polygons would support the global evaluation of protected area effectiveness using biological monitoring data collected inside and outside no-take areas, and would provide marine industry users with greatly improved information on critical habitats for their screening purposes (Martin *et al.*, in prep.). Moreover, including information on the vertical dimensional aspect of no-take areas (e.g. benthic and water column restrictions) would provide the necessary information for greatly refined conservation priority setting.

Quality assurance

In order to improve the quality of MPA data within the WDPA there needs to be additional focus on engaging with all relevant stakeholders. At the national level there needs to be improved coordination between the relevant data providers with regard to MPAs, this includes discussion between State entities as well as between State and non-State entities. Inclusion of MPA data into the WDPA needs to be formalized with data providers, and contacts with UNEP-WCMC need to be enhanced and expanded. Over the last few years there has been an increased engagement on behalf of UNEP-WCMC with the UNEP Regional Seas Conventions and Action Plans and their Secretariats, which has led to an increased profile of MPAs and improvement of data. Continuing this engagement and formalizing the workflows is essential for long-term improvement in the quality and quantity of MPA data within the WDPA.

Meeting Aichi Target 11

With 10.92% of Territorial Seas covered by MPAs, it appears as if the Aichi Target 11 aspiration to protect '10% of coastal and marine areas' may have been met within this jurisdictional area. The fact that MPA coverage in all jurisdictional areas

has been increasing consistently, particularly in coastal areas, demonstrates a positive political and local willingness to drive marine conservation efforts forward. However, Aichi Target 11 urges CBD Contracting Parties to go far beyond coverage statistics (Woodley *et al.*, 2012). Analyses are required to assess the extent to which habitat representation has been achieved within global MPAs, whether MPAs are well connected, and how conservation priorities might be set as a result (Brooks *et al.*, 2004; Spalding *et al.*, 2008, 2013; Butchart *et al.*, in prep.).

Far more challenging is the assessment of whether essential ecosystem services have been adequately incorporated into MPA networks. In many cases, larger MPAs and networks tend to be situated where there are fewer people (Spalding *et al.*, 2013) suggesting that we are not currently safeguarding the ecosystem services that are most heavily used and valued. Effective site management is essential if MPAs are to deliver their intended conservation objectives, but additional work is necessary to increase uptake of Protected Area Management Effectiveness (PAME) evaluation systems established by various global agencies, including inter alia WWF, World Bank, and IUCN (Hockings *et al.*, 2000) in order to enable progress assessments to be made (Bertsky *et al.*, 2012). Similarly, equitable management of MPAs and other effective area-based conservation measures is hard to assess under the current approach to data collation within the WDPA, as several countries do not recognize community identified sites, such as Locally Managed Marine Areas (LMMAs). Moreover, reaching agreement upon what is meant by the CBD definition of 'other effective area-based conservation measures' will be extremely challenging (Spalding *et al.*, 2013) and therefore the necessary data required for progress evaluation is still very limited (Bertsky *et al.*, 2012).

Maintaining the essence of an official, mandated database

As described, there are still issues that must and will be addressed to improve the MPA data in the WDPA, as one might expect where data are sourced from 193 Member States and numerous international and regional agencies and organizations. While improvements are constantly being made to the WDPA, it is important to remember the mandated and country-inclusive approach taken by the WDPA, which is to first

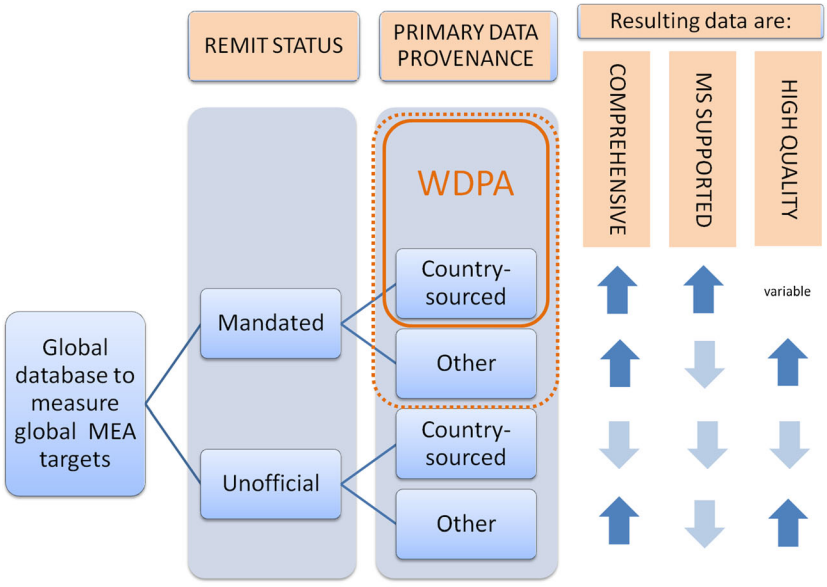

Figure 9. Diagram of different conceptual approaches to gathering global data, indicating higher or lower (or variable) likelihood of the resulting data being comprehensive, Member State supported and high quality. The solid orange box represents the position of the WDPA currently, while the dashed box represents an alternative position the WDPA could be in that would facilitate the improvement of data.

and foremost recognize national sovereignty and the rights of the Member State data providers. While this approach does present a challenge to obtaining complete data, due to political or bureaucratic issues, it remains central to the aim of the WDPA to provide State-sanctioned data to enable calculation of Member State endorsed global targets.

Fundamentally, data gathering mechanisms for reporting global targets can be simply classified according to whether the remit to collect data is either officially mandated by intergovernmental or national agencies or is unofficial, research-led collection. In either case, the data being collected can either be sourced from national bodies or from alternative independent sources, although Member States would be significantly more likely to respond to a request for data that is mandated by the UN (e.g. through a CBD Decision). The combination of remit and data-gathering approach will strongly influence how comprehensive the resulting picture is likely to be (i.e. data from all around the world), the quality of the data themselves (i.e. how well the data reflect reality), and how fully Member States would support any subsequent data interpretation. Figure 9 is a decision tree depicting the conceptual options described above and suggesting whether each approach has a higher or lower likelihood of producing comprehensive, Member State supported, high quality data.

In real terms, the WDPA is a mandated database that collates Member State data, making it comprehensive and providing it with the CBD Contracting Party endorsement required to be the mechanism for CBD Aichi Target reporting. However, the issues raised in this paper, such as missing or inaccurate boundary or attribute information from data providers, highlight the challenges inherent in managing and maintaining a high quality dataset. Since the support of Member States is the critical prerequisite to the WDPA success, any programme of improvements would need to be strategically managed to ensure that such official endorsement would not be compromised.

Rather than attempting to adjust or correct for missing information from Member States, one solution to improve the quality of the WDPA data would be to broaden the scope of the database to include non-State-sanctioned data that are clearly identified as separate from official data. While State-provided protected areas would remain the source of the UN official list of protected areas and Aichi Target 11 progress reporting, the WDPA could accept data from other reputable international organizations responsible for protected area management to complement the existing information. Where discrepancies between data arose, this would ideally result in dialogue between the relevant Member State focal point and the alternative data provider, facilitated by UNEP-WCMC as a means to reconcile the information and improve the quality of the data from that country. In this way, the WDPA would remain the most comprehensive database of protected areas and could retain the support of Member States, but would continue to improve for global target assessments and other protected area analyses, both globally and regionally.

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