LETTER

Toward representative protection of the world's coasts and oceans—progress, gaps, and opportunities

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Abstract

Marine conservation lags behind terrestrial in the establishment of protected areas. This was recognized by the Convention on Biological Diversity, whose members, in 2004, agreed to establish "comprehensive, effectively managed, and ecologically representative" systems of marine protected areas (MPAs) by 2012. Halfway toward this target date, we look at the coverage of the world's 5045 MPAs from a biogeographic perspective. Only 4.09% of continental shelf areas are incorporated within MPAs, although coverage rises to 12.1% in a narrow coastal belt. Approximately half of all marine ecoregions have less than 1% MPA coverage across the shelf, but this is highly variable, and (8%) of ecoregions have >30% protection. Protection is greatest in the tropical realms, while temperate realms remain poorly represented. Given that that many sites lack effective management, even these low estimates of coverage are an optimistic measure of the extent of effective marine conservation.

Introduction

Marine protected areas (MPAs) are a valuable tool in efforts to secure, or indeed restore marine biodiversity. They are also increasingly seen to be having a wider role in supporting the sustainable use of marine resources (De Fontaubert *et al.* 1996; Gell & Roberts 2003; Halpern 2003; Norse & Crowder 2005; Roberts *et al.* 2005). Recognizing this importance, in 2004 all nations signatory to the Convention on Biological Diversity (CBD) agreed to establish "comprehensive, effectively managed, and ecologically representative national and regional systems" of MPAs by 2012 (Convention on Biological Diversity 2004). In 2006, this target was quantified to "at least 10% of each of the world's marine and coastal ecological regions effectively conserved by 2010" (Convention on Biological Diversity 2006).

Other influential groups have laid similar stress on the need to expand marine conservation systematically. For example, the outputs of the 2003 World Parks Congress (Durban Accord and Durban Action Plan) called for "strictly protected areas" in the marine environment that should cover "at least 20–30% of each habitat" (IUCN 2005, Recommendation V.22).

The terms "habitat" and "ecological region" were not formally defined either at the 2003 World Parks Congress or in the CBD outputs, but imply defined and spatially identifiable units of ecological integrity or coherence. In some regions, such spatial frameworks for marine conservation planning have already been established using generalized biogeographic patterns of species and communities (for example, Thackway & Cresswell 1998; Dinter 2001; Commonwealth of Australia 2006; Wilkinson *et al.* 2006; Ardron 2008). More recently, a new global biogeographic classification, termed marine ecoregions of the world (MEOW), was prepared, circulated to member states of the CBD, and then revised and published (Spalding *et al.* 2007). This classification provides a system of realms, provinces, and ecoregions and currently covers continental shelf areas (work is underway on equivalent off-shelf classifications (Agostini *et al.* 2008), but is not yet finalized). In common with other such approaches (Olson *et al.* 2001; Abell *et al.* 2008), the MEOW classification provides a subdivision of the ecological landscape,

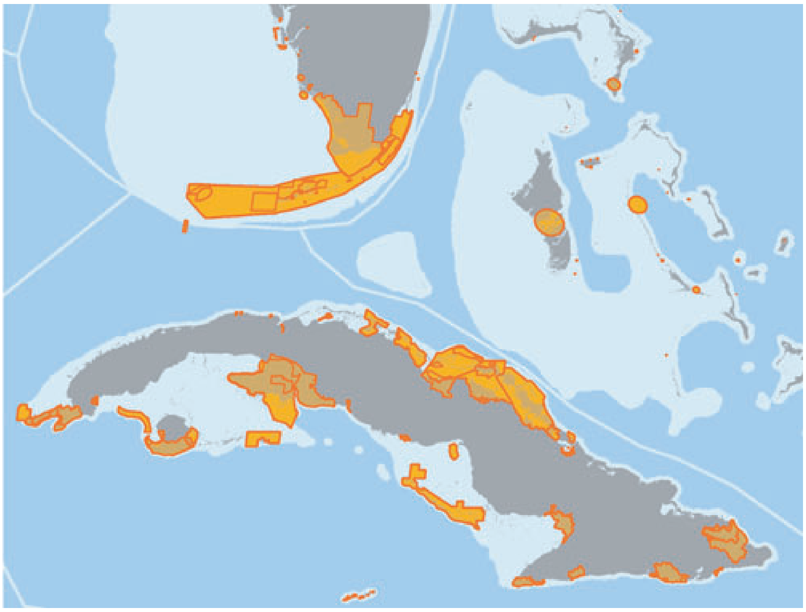

Figure 1 Marine protected areas in parts of the Floridian, Bahamian, and Greater Antilles ecoregions. The shelf areas (< 200 m depth) which form the spatial units for this assessment are marked in pale blue, MPAs are in orange. Most sites are tightly linked to coastlines and islands.

reflecting evolutionary patterns, including centers of endemism, as well as current, functional, patterns of ecosystems, communities, and species. It attempts to summarize across groups, rather than focus on particular taxa or habitats.

Such classifications can be used to maximize effectiveness of conservation interventions, notably ensuring more complete representation of biodiversity within protected areas networks. The MEOW classification has already been used by the Scientific and Technical Review Panel for the Ramsar Convention on Wetlands and has been recommended for adoption and use by parties to that convention "as an appropriate global standard for the biogeographic regionalization of the coastal and near-shore marine environment" (Ramsar Convention 2008). The present work uses this classification in a first complete biogeographic assessment of the MPA coverage worldwide.

Two other recent works have looked at the global coverage of MPAs and included some overlays of specific marine habitats, including coral reefs and mangrove forests (Chape *et al.* 2005; Wood *et al.* 2008). Such approaches are valuable, but as most marine habitats remain unmapped, they can only give a partial picture, and focus on better-known and generally better-protected habitats. These studies were also broadly based, and gave no further attention to the important spatial variance within these habitats, such as centers of endemism or diversity. The present approach provides a more complete review of the biodiversity coverage of the world's MPAs, using the MEOW biogeographic framework that incorporates patterns of endemism and diversity across ecosystems in coastal and shelf waters. It also works with a more detailed and recent version of the MPA database than was available for the earlier studies.

Methods

Two related databases hold global data on MPAs. The World Database of Protected Areas (WDPA, see www.unep-wcmc.org/wdpa/) is the most comprehensive global spatial dataset on protected areas, while MPA Global (www.mpaglobal.org/home.html) has been developed from WDPA, with considerable expert review and input. The two databases are compatible and reintegrated on a regular basis to ensure that there are no discrepancies between them. Up until January 2008 immediately prior to undertaking this work, we performed another reintegration to create a best MPA database within the structure of the WDPA, held within a geographical information system (GIS).

The final MPA GIS dataset consisted of 5,045 sites out of a global total held on the WDPA of 110,000 sites (see Figure 1 for a sample and Table S1 in the supporting information online for a full list of sites). This represents a considerable increase in the number of sites used in the earlier studies—-Chape *et al.* (2005) reported 4,254 MPAs, while Wood *et al.* (2008) reported 4,435—reflecting both increasing numbers of sites over time, but also improvements in the coverage of the database. While there may still be gaps, we are confident that the dataset is broadly representative, with missing data largely restricted to small or poorly protected sites whose existence and coverage is not always well reported. Spatial boundary (polygon) information was held for 77% of sites, but this included most of the largest sites and so represented 95% of the total MPA area. For the 1,177 sites with no polygon boundary, a circular area equal to the total site area was assigned around the central coordinates (point). For 195 sites, the total site area was also unknown. Such poorly documented sites in the WDPA are typically small, and so each was assigned an area of 1 km^2, a figure well below the median value (5 km^2 for MPAs with no polygons). Such a figure would ensure that their presence was detected in the analysis but could not unduly lift protection estimates for any ecoregion. Further information on the extent of no-take areas (zones or sites, where no fishing is permitted) was held for 1,536 sites (30% of the total), of which 460 were either entirely or partially no-take. This degree of coverage was too incomplete for any detailed analysis, but was reviewed to look for general trends.

For the biogeographic data, we used a global GIS dataset of the MEOW classification (Spalding *et al.* 2007). These extended from a high-resolution global coastline (USDMA not dated) out to a line that was buffered 5 km beyond the 200-m depth contour (British Oceanographic Data Centre 2003). This buffered shelf has been used by others (Halpern *et al.* 2008) and now represents the standard layer for marine ecoregions analyses—the buffer recognizes the ecological influence of shelf or coastal biotas into continental slope and near-shelf pelagic systems, particularly where shelves are narrow, and also where the influence of the coastal region is much broader such as around oceanic islands. It further matches with the observation that as a measure of shelf edge location, the 200-m depth contour is both approximate and represents a zone of transition rather than a sharp ecological boundary (Spalding *et al.* 2007). A problem we encountered with all global coastlines was that they are approximated to the mid-tide line. This conflicts with the IUCN definition of MPA, which includes all areas to the upper intertidal. There was no clear way to avoid this mismatch; however, part of our spatial analysis used an inland buffer which would capture those areas, and even entire sites, excluded from the shelf-based analysis.

MPAs were intersected with the marine ecoregions, provinces, and realms to generate summary biogeographic statistics within a GIS. In our first spatial analysis, we used the raw MPA GIS data to generate site-specific outputs. In a second spatial analysis, we used a dissolved MPA GIS dataset (in which all sites were merged in a single layer to eliminate double-counting of overlapping designations) to generate global representation summary statistics, including a summary of off-shelf protection. We undertook a third spatial analysis to look at MPA coverage within a narrow coastal belt, buffered 1 km either side of the global coastline. This latter analysis was undertaken because the coastal and intertidal belt is host to distinct species and ecosystems, which we hypothesized to be disproportionately well covered by a preponderance of coastal sites in the global MPA database (see Figure 1). We used a 2-km belt rather than a linear measure of coastline protected because: (1) it would ensure inclusion of a majority of intertidal zones which can be extensive in area; (2) it reduces problems of misalignment that occur when overlaying spatial datasets that use different coastlines; and (3) it would capture the upper intertidal areas excluded from the shelf-based analysis.

Following the spatial analyses, 653 sites (281 points, 372 polygons) had no apparent marine area. A few were off-shelf and thus correctly excluded. Others were excluded because their marine elements are restricted to the upper intertidal or upper estuarine waters (they were therefore still included in the coastal belt analysis). There were also unavoidable errors linked to misalignment of the coast, sometimes because the protected area information was poorly referenced, but in other cases because of the relatively low resolution (1:250,000) of the coastline in relation to high-resolution MPA boundaries (these sites were still mainly captured in the coastal belt analysis). Although small in overall area, a *post hoc* manual intervention was undertaken for the shelf-based statistics, adding in area information for 261 sites for which we had independent verification that they included subtidal elements and for which a reliable marine area was available. The primary source for this non-GIS area information was the MPA Global database (Wood *et al.* 2008). The total protected area added by this process was 3,349 km^2 (0.28% of the total shelf MPA coverage).

Results

Marine protected areas cover 1,200,113 km^2 or 4.09% of the total continental shelf area. There is a particular concentration on intertidal and near coastal waters and MPAs occupy 12.10% of the coastal belt. A further 1,388,279 km^2 of protected areas extend into off-shelf waters, but these are entirely contained within 200 nm of coastal areas. Combined these give a global MPA coverage of 2,588,392 km^2, which represents only 1.91% of waters within EEZ areas, or 0.717% of the entire world ocean surface.

Figure 2 shows the results summarized by ecoregions (the associated statistics are provided in Table S2 of the supporting information online). The same information summarized by realm and province is presented in Table 1. Around half of all ecoregions (115) have less than 1%

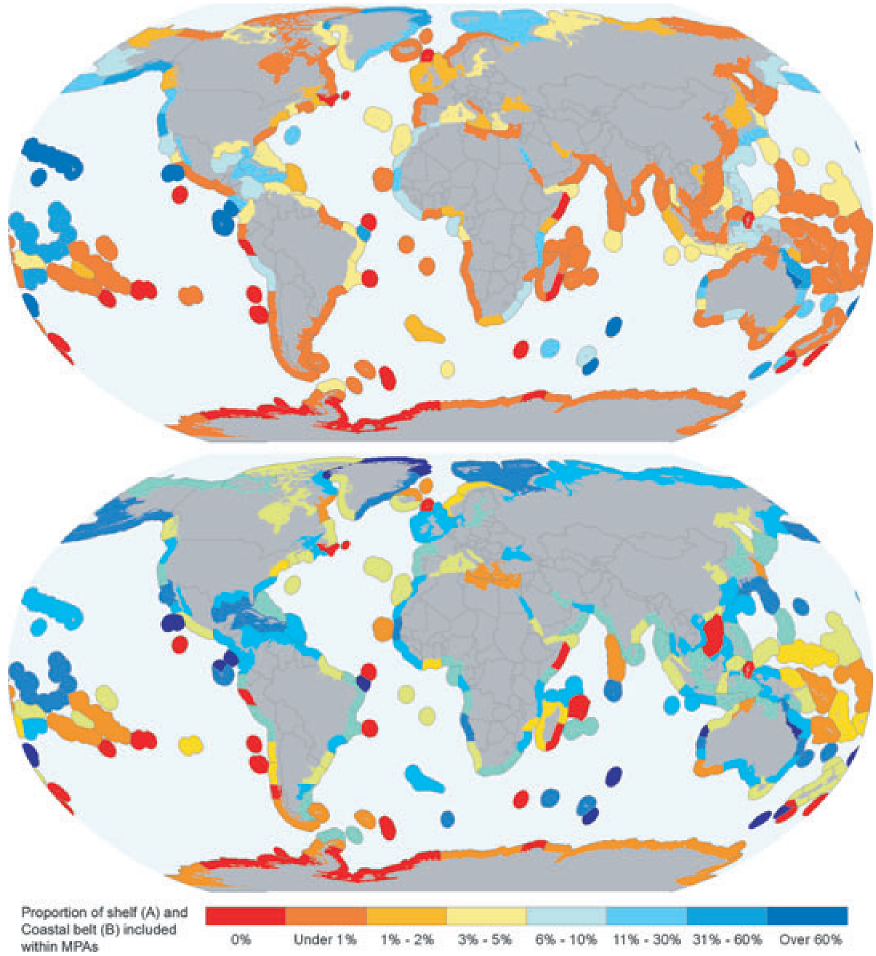

Figure 2 Proportion of MPA coverage by ecoregion. Upper map (A) is the overall coverage (entire shelf). Lower map (B) is for the 2 km coastal belt only. Note that ecoregions boundaries in both maps are drawn out to an approximate 200-nm buffer—this is for ease of visualization only and the proportional coverage refers to much smaller spatial areas.

MPA coverage across shelf, with 21 of these (9%) lacking a single MPA. At broader scales, 18 provinces (29%), across the globe in eight of the 12 realms, have less than 1% coverage. At the other end of the spectrum, a small number of ecoregions have extensive MPA coverage: 42 (18% of the total) have greater than 10% MPA coverage and 26 (11%) have greater than 20%. These summary parameters are heavily influenced by a small number of large MPAs—147 MPAs cover shelf areas greater than 1000 km^2, and the 10 largest sites between them make up over 50% of the total shelf area protected. Just one of these, the Great Barrier Reef Marine Park in Australia, accounts for over 20% of the global total shelf MPA coverage.

Off-shelf MPA coverage cannot be usefully classified down to shelf-based ecoregions, but to give some idea of the geographic distribution of these areas, a summary at realm level is provided in Table 2. Although the total area covered is larger than that of shelf-based MPAs, the distribution is different, with the influence of few large sites being much greater than for near-shelf areas, and with many regions showing little or no coverage. Only four sites make up over 72% of the total off-shelf protection (Phoenix Islands Protected Area, Papahanaumokuakea Marine National Monument in Hawaii, Macquarie Island Marine Park and the Galapagos Marine Reserve).

There is considerable variance in the uptake of no-take areas. Summary information is given in terms of numbers of sites in Table 1. For a few areas the available information on no-take coverage is more complete, and Table 3 gives the no-take coverage of the shelf area for the 16 ecoregions for which known no-take coverage is over 1%.

The coastal belt experiences much higher levels of protection than shelf areas overall. Only around 21% of ecoregions have less than 1% MPA coverage—this figure

Table 1 MPA coverage summarized to provinces and realms. The final three columns refer to the fisheries closure data that were gathered for approximately one third of all sites (Wood *et al.* 2008). These data differentiate sites that are no-take (no fishing permitted), partially no-take (although the extent or proportion is not always known), or known not to include any area that is no-take.

Realm	Province	Number of MPAs	Total MPA area (km^2)	Shelf area (km^2)	Propn. of shelf within MPAs	Propn. of coast within MPAs	No-take MPAs	Part no-take	Zero no-take
Arctic		**122**	**361,162**	**7,591,303**	**4.76%**	**16.85%**	**0**	**1**	**36**
1	Arctic	122	361,162	7,591,303	4.76%	16.85%	0	1	36
Temperate Northern Atlantic		**1877**	**68,750**	**4,174,903**	**1.65%**	**7.87%**	**11**	**51**	**800**
2	Northern European Seas	799	27,360	1,746,361	1.57%	9.08%	0	3	506
3	Lusitanian	59	8,391	307,424	2.73%	8.85%	0	1	2
4	Mediterranean Sea	237	11,240	688,851	1.63%	1.74%	11	46	25
5	Cold Temperate Northwest Atlantic	596	10,889	889,788	1.22%	5.40%	0	1	267
6	Warm Temperate Northwest Atlantic	155	7,489	372,146	2.01%	22.23%	0	0	0
7	Black Sea	31	3,380	170,333	1.98%	10.35%	0	0	0
Temperate Northern Pacific		**580**	**166,210**	**3,029,117**	**5.49%**	**17.17%**	**0**	**6**	**143**
8	Cold Temperate Northwest Pacific	81	21,295	1,619,473	1.31%	6.39%	0	0	22
9	Warm Temperate Northwest Pacific	64	15,387	665,950	2.31%	21.66%	0	0	16
10	Cold Temperate Northeast Pacific	360	112,004	556,732	20.12%	23.20%	0	3	104
11	Warm Temperate Northeast Pacific	75	17,524	186,962	9.37%	20.65%	0	3	1
Tropical Atlantic		**612**	**113,977**	**2,175,394**	**5.24%**	**18.58%**	**46**	**16**	**43**
12	Tropical Northwestern Atlantic	524	75,323	1,019,155	7.39%	25.41%	44	14	42
13	North Brazil Shelf	24	9,614	505,947	1.90%	7.72%	0	1	1
14	Tropical Southwestern Atlantic	15	9,168	198,487	4.62%	6.56%	2	1	0
15	St. Helena and Ascension Islands	4	2	1,263	0.18%	4.01%	0	0	0
16	West African Transition	16	7,649	73,770	10.37%	21.73%	0	0	0
17	Gulf of Guinea	29	12,220	376,772	3.24%	14.06%	0	0	0
Western Indo-Pacific		**242**	**32,280**	**2,246,171**	**1.44%**	**7.88%**	**22**	**10**	**11**
18	Red Sea and Gulf of Aden	18	9,970	286,320	3.48%	8.02%	0	0	6
19	Somali/Arabian	26	4,205	393,165	1.07%	7.79%	0	0	3
20	Western Indian Ocean	91	7,449	492,777	1.51%	9.69%	16	9	2
21	West and South Indian Shelf	26	1,980	389,574	0.51%	6.83%	0	1	0
22	Central Indian Ocean Islands	31	1,259	79,363	1.59%	3.71%	5	0	0
23	Bay of Bengal	22	1,314	289,807	0.45%	5.02%	0	0	0
24	Andaman	28	6,104	315,165	1.94%	8.90%	1	0	0
Central Indo-Pacific		**910**	**335,976**	**5,917,446**	**5.68%**	**9.25%**	**130**	**61**	**12**
25	South China Sea	77	3,333	544,927	0.61%	6.93%	0	0	2
26	Sunda Shelf	142	6,620	1,845,154	0.36%	6.74%	0	3	0
27	Java Transitional	31	1,888	67,267	2.81%	16.25%	0	1	0
28	South Kuroshio	27	3,250	42,685	7.61%	24.98%	0	0	5
29	Tropical Northwestern Pacific	45	485	58,446	0.83%	7.76%	8	7	2
30	Western Coral Triangle	353	42,527	986,557	4.31%	8.55%	100	26	0
31	Eastern Coral Triangle	44	1,171	231,271	0.51%	1.75%	8	10	0
32	Sahul Shelf	20	8,769	1,322,713	0.66%	7.08%	0	0	1
33	Northeast Australian Shelf	80	244,470	292,417	83.60%	60.62%	1	4	1
34	Northwest Australian Shelf	11	6,520	306,319	2.13%	8.33%	2	4	1
35	Tropical Southwestern Pacific	77	14,592	210,383	6.94%	2.70%	11	3	0
36	Lord Howe and Norfolk Islands	3	2,352	9,308	25.27%	38.93%	0	3	0
Eastern Indo-Pacific		**115**	**28,067**	**151,087**	**18.58%**	**8.93%**	**8**	**6**	**8**
37	Hawaii	68	23,970	31,670	75.69%	29.68%	4	5	8
38	Marshall, Gilbert and Ellis Islands	4	793	49,561	1.60%	2.17%	1	0	0
39	Central Polynesia	28	3,144	16,643	18.89%	22.35%	1	1	0
40	Southeast Polynesia	10	140	47,838	0.29%	0.44%	2	0	0
41	Marquesas	2	19	4,659	0.40%	2.90%	0	0	0
42	Easter Island	3	1	716	0.20%	1.87%	0	0	0

Continued

Table 1 Continued.

Realm	Province	Number of MPAs	Total MPA area (km^2)	Shelf area (km^2)	Propn. of shelf within MPAs	Propn. of coast within MPAs	No-take MPAs	Part no-take	Zero no-take
Tropical Eastern Pacific		**76**	**23,931**	**255,738**	**9.36%**	**18.11%**	**1**	**1**	**0**
43	Tropical East Pacific	75	7,325	239,044	3.06%	13.91%	1	0	0
44	Galapagos	1	16,606	16,694	99.47%	58.03%	0	1	0
Temperate South America		**89**	**5,000**	**1,705,777**	**0.29%**	**2.87%**	**0**	**0**	**1**
45	Warm Temperate Southeastern Pacific	8	1,948	150,487	1.29%	3.50%	0	0	0
46	Juan Fernández and Desventuradas	0	–	1,827	0.00%	0.00%	0	0	0
47	Warm Temperate Southwestern Atlantic	51	1,278	563,200	0.23%	12.10%	0	0	1
48	Magellanic	28	1,746	988,375	0.18%	1.34%	0	0	0
49	Tristan Gough	2	28	1,888	1.50%	17.60%	0	0	0
Temperate Southern Africa		**26**	**4,230**	**285,228**	**1.48%**	**14.91%**	**8**	**4**	**8**
50	Benguela	10	883	161,545	0.55%	20.21%	1	1	3
51	Agulhas	15	2,647	122,750	2.16%	6.78%	7	3	5
52	Amsterdam-St Paul	1	700	934	74.98%	66.49%	0	0	0
Temperate Australasia		**350**	**38,280**	**1,027,362**	**3.73%**	**11.20%**	**60**	**14**	**14**
53	Northern New Zealand	31	1,776	49,354	3.60%	3.25%	10	0	0
54	Southern New Zealand	55	285	241,029	0.12%	2.44%	19	0	1
55	East Central Australian Shelf	103	12,611	69,093	18.25%	33.79%	4	6	8
56	Southeast Australian Shelf	82	1,581	241,502	0.65%	12.62%	16	3	2
57	Southwest Australian Shelf	73	13,089	335,464	3.90%	9.13%	9	4	3
58	West Central Australian Shelf	6	8,938	90,922	9.83%	26.83%	2	1	0
Southern Ocean		**46**	**22,251**	**788,347**	**2.82%**	**2.99%**	**2**	**2**	**0**
59	Subantarctic Islands	7	16,189	93,078	17.39%	38.50%	1	2	0
60	Scotia Sea	27	1,716	162,522	1.06%	1.41%	0	0	0
61	Continental High Antarctic	11	177	496,357	0.04%	0.06%	0	0	0
62	Subantarctic New Zealand	1	4,169	36,390	11.46%	68.54%	1	0	0
GLOBAL TOTAL		**5045**	**1,200,113**	**29,347,874**	**4.09%**	**12.10%**	**288**	**172**	**1076**

Table 2 Total MPA coverage, including off-shelf areas, summarized by realm

Realm	Total MPA area in realm (km^2) within MPAs	Total realm area within 200 nm (km^2)	Proportion of 200 nm realm area within MPAs
Arctic	408,038	11,914,675	3.42%
Temperate Northern Atlantic	76,023	11,263,260	0.67%
Temperate Northern Pacific	185,344	9,788,232	1.89%
Tropical Atlantic	189,126	13,602,783	1.39%
Western Indo-Pacific	33,355	14,405,880	0.23%
Central Indo-Pacific	466,407	27,864,783	1.67%
Eastern Indo-Pacific	757,572	19,045,509	3.98%
Tropical Eastern Pacific	162,755	4,364,139	3.73%
Temperate South America	5,563	6,401,295	0.09%
Temperate Southern Africa	4,245	1,922,585	0.22%
Temperate Australasia	54,746	5,444,748	1.01%
Southern Ocean	245,218	9,706,434	2.53%
Grand Total	2,588,392	135,724,322	1.91%

Table 3 The 16 ecoregions with known areas of no-take coverage > 1% on the continental shelf. For Hawaii the proportion no-take will increase to over 50% when the Papahanaumokuakea Marine National Monument becomes fully no-take the coming years.

Ecoregion	Province no-take	Area of no-take (km^2)	Proportion of ecoregion
Kermadec Island	Northern New Zealand	1,673	99.65%
Heard and Macdonald Islands	Subantarctic Islands	6,362	77.80%
Coral Sea	Tropical Southwestern Pacific	8,513	32.00%
Fernando de Naronha and Atoll das Rocas	Tropical Southwestern Atlantic	138	31.46%
Central and Southern Great Barrier Reef	Northeast Australian Shelf	56,184	29.48%
Macquarie Island	Subantarctic Islands	1,139	27.16%
Auckland Island	Subantarctic New Zealand	4,169	23.67%
Torres Strait Northern Great Barrier Reef	Northeast Australian Shelf	17,157	16.85%
Shark Bay	West Central Australian Shelf	6,935	12.42%
Hawaii	Hawaii	2,181	6.89%
Lord Howe and Norfolk Islands	Lord Howe and Norfolk Islands	495	5.32%
Chagos	Central Indian Ocean Islands	1,158	4.47%
Natal	Agulhas	827	3.61%
Samoa Islands	Central Polynesia	144	1.95%
Bermuda	Tropical Northwestern Atlantic	15	1.65%
Aegean Sea	Mediterranean Sea	1,525	1.21%

includes the same 21 ecoregions with no MPAs, and only 27 others with less than 1% MPA coverage. Only three provinces have less than 1% protection (one of these, the continental high Antarctic, represents a special case, see below). By contrast, 93 ecoregions (40%) have greater than 10% MPA coverage and 58 (25%) greater than 20%.

Discussion

Examining the global network of MPAs over time, Wood *et al.* (2008) concluded that at current rates of MPA designation, the targets set by the international community will take decades, rather than the 4 years remaining, before the target deadlines are met. We show that the biogeographic scope of this failure is as worrying as the temporal failure. Ideal biogeographic representation would require targets to be met in every ecoregion. The global map shows instead a highly unbalanced picture, with half of all ecoregions showing less than 1% MPA coverage, and only 18% having coverage greater than 10%.

Where low coverage is maintained across multiple adjacent ecoregions, particularly where entire provinces or realms appear to be poorly covered, concerns should be further heightened. Such broader-scale biogeographic regions represent unique biotas formed over evolutionary time frames, rich in endemic species (Briggs 1974; Spalding *et al.* 2007). Their degradation will increase the likelihood of marine extinctions; reduce capacity for resilience and recovery; and may further threaten the broad array of ecosystem services derived from these marine resources.

Even the low MPA coverage results cannot be equated with the coverage of effective marine protection. The ineffective nature of many MPAs has been widely noted (McClanahan 1999; Jameson *et al.* 2002; Appeldoorn & Lineman 2003; Mora *et al.* 2006), and is a limitation in this study because comprehensive global information on the effectiveness of protection remains unavailable. With this limitation noted, we still maintain that the most MPAs represent at least some advance over "nonprotection" (Spalding *et al.* 2006; Lester & Halpern 2008). The concern remains, however, and clearly more needs to be done to increase coverage and to improve effectiveness. MPAs also need to be placed into a broader framework of management which incorporates, inter alia, watershed management, coastal zone planning, shipping regulations, and basin-wide fisheries controls.

Particular concern must be expressed for the temperate realms of the Northern Atlantic, South America, and Southern Africa. These realms include ecosystems such as the deep coral communities of the northern Atlantic, the upwelling waters of the Benguela Current and the fjords and rich wide shelf areas of the Magellanic Province. The coastal belt coverage from these same three realms remains low, with large gaps throughout South America, the Mediterranean and much of the cold temperate northwestern Atlantic. The lack of no-take MPAs in these realms is also of concern. Even the Northern Temperate Atlantic, which has 1,877 MPAs, double the number of any other realm, has only 62 no-take reserves, only

11 of which are fully no-take. Given the success of such reserves in other realms in supporting fisheries and in engendering community support for increasing protection, this realm-wide paucity is a particular worry for sustainable resources management and species conservation (see also Ballantine & Langlois 2008).

A more complex picture emerges for the polar realms. Although having MPA coverage of only 2.82% of its shelf area, the Southern Ocean has a relatively robust legal framework for biodiversity protection: its oceanic islands are under national jurisdictions and have among the highest MPA coverage of any provinces, while continental Antarctica falls under the international Antarctic Treaty System, with levels of protection broadly equivalent to many MPAs (Croxall & Trathan 2004). In the Arctic, summary parameters are strongly influenced by a number of large sites covering wide shelf areas across Greenland, Europe and Russia, and there is much lower coverage in North America.

Across the Indo-Pacific, MPA coverage is highly variable. The existence of several large MPAs such as Phoenix Islands Protected Area in Kiribati, the Great Barrier Reef Marine Park in Australia and the Papahanaumokuakea Marine National Monument in Hawaii, greatly inflates average spatial coverage at realm levels; however, wide gaps remain, notably across parts of the Western Indo-Pacific and in the species rich Eastern Coral Triangle province.

The Temperate Northern Pacific realm, particularly in the eastern provinces stretching along the entire North American continental coastline, shows high coastal and cross-shelf MPA coverage, offering potential benefits from connectivity between protected areas. Similarly, the Tropical Atlantic appears to have high MPA coverage in a number of ecoregions, especially across the Caribbean. This is interesting politically because the MPA coverage is spread across countries with a broad array of political and socioeconomic characteristics. Such regional perspectives can of course hide important gaps. For example, in the tropical Atlantic realm the extensive and important MPA systems off Cameroon and Gabon are masking the lack of any MPA coverage in the vast Niger Delta—one of the largest contiguous mangrove forests in the world that is now being rapidly degraded (Corcoran *et al.* 2007; James *et al.* 2007).

Marine resources are in a perilous state (UNEP 2006; Halpern *et al.* 2008), and MPAs have been widely shown to offer a powerful tool to help mitigate threats and to support the maintenance of ecosystem services from the oceans. Successful and efficient marine conservation requires systematic planning that takes into account the natural patterns of ecological systems over space and time. These considerations have been strongly endorsed by the global community through the CBD, the Ramsar Convention, and the members of the World Conservation Union (IUCN). The year 2008 marks the half-way mark toward the CBD target of establishing representative marine protected areas by 2012. Despite these observations, we found that in every realm and almost every province, ecoregions with low or no MPA coverage are common. Nations and territories need to develop policies to remedy this low MPA coverage and to extend attention to off-shelf areas, not only to meet their commitments under the CBD, but to protect marine biodiversity and indeed humans who depend on it.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Full listing of the MPAs used in the assessment.

Table S2. Summary information of MPA coverage by ecoregion for the continental shelf and the coastal belt analyses (as illustrated in Figure 2).

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