



Supporting Online Material for

Coral Reefs and the Global Network of Marine Protected Areas

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Supporting Online Material

Materials and Methods

Reference database

Marine Protected Areas in the 2005 World Database on Protected Areas (*S1*) were overlaid on digitized maps of the world's coral reefs (see below) to create a reference database of the world's coral reef MPAs. MPAs were geo-referenced as polygons (401 MPAs in the final database) and, where boundary data were not available, as point records of the central position of the MPA (579 MPAs in the final database). For the analysis, point records were converted into circular shapes of the same area as the MPA and were merged with the polygons for overlay on the coral reef maps. All MPAs overlapping coral reefs were included in the database for verification (see below). We assessed the potential bias in using circular MPA boundaries by comparing the area of coral reefs inside the MPAs for which polygons were available with the area of coral reefs that these MPAs would cover if they were circular in shape. We found that circular shapes tend to underestimate by 23% the coral reef area covered. However, this large difference was driven mainly by the very few existing large MPAs. Removing the largest eight (out of the 401) MPAs reduced the underestimation to only 7%. None of the MPAs with point records matched the size of those suggesting that the calculations in our analysis are underestimated in the range of 7% or less.

Database verification

The reference database contained 1 344 MPAs belonging to 102 countries. Contact information for local managers and researchers was obtained using the internet, published reports and papers. This resulted in a directory of 1 073 people who were initially contacted by email to enquire as to the status of the MPAs in their countries. Positive responses were obtained for 94 countries. For the remaining countries, we used recent reports on the status of coral reefs (*S2–S4*), searched the internet and made telephone calls to ensure that some level of verification was available for each country. This exercise resulted in the deletion of 521 MPAs from, and the addition of 157 MPAs to, the reference database. The coverage of coral reefs by the global network of MPAs could have been biased upwards by 1.2% if the MPAs that do not actually exist had been included, or downwards by 0.5% if those that do exist but were not included on the original list had been ignored. The main causes of deletion were proposed but not formally

designated MPAs, duplicated records (e.g., different names for the same areas), areas whose boundaries were on the coast but did not include any management of the sea, and areas that were embedded within larger MPAs. Some gaps in the database remain, particularly in south-east Asia, where countries like the Philippines and Indonesia have many community MPAs that have yet to be documented. However, such areas are relatively small in size (a few hectares), many have yet to be recognized by central governments, and only a handful achieve satisfactory conservation status (S2, S3).

Management classification of MPAs

MPAs were classified by their regulations on extraction as either no-take, take or multipurpose. Multipurpose MPAs were defined as zoned areas including take and no-take grounds. This category was further divided into those that prohibit commercial harvesting (category A) and those that do not (category B). This information and that below on poaching were obtained directly from managers, researchers and written reports during the process of database verification (see above).

Management performance of MPAs

Here we used a quantification of management performance based on levels of compliance. That is, on whether the levels of poaching inside MPAs were none, low, medium or high. Poaching can be deemed a direct reflection of the extent to which other management activities inside the MPAs are operating (S5) and it can be perceived by visitors to MPAs, which facilitates obtaining data. Poaching is also of relevance to biological responses of populations inside MPAs and theoretical models have indicated that even mild levels of poaching, particularly when MPAs are small, can diminish any positive effect that MPAs may have (S6, S7). We assessed the extent to which variations among observers were likely to influence our measurement of poaching by comparing data on the levels of poaching for 135 MPAs for which we received data from more than one source. The comparison of these results indicated that in 49% of the cases, those interviewed agreed upon the exact level of poaching and in ~90% they agreed to within one level above or below a given value. In absolute terms 96% of the cases agreed upon whether poaching was present or not. This suggests that, in general, there is a large level of agreement on the results used here.

External risks to MPAs

To account for the potential effect of external threats on the effectiveness of MPAs, we used the combined reef threat indicator developed by The World Resources Institute, The International Center for Living Aquatic Resources Management, and The World Conservation Monitoring Centre (WCMC) (S8). This database combines data on coastal development, overexploitation, erosion and marine- and inland-based pollution into a single index, which classifies the world's coral reefs as at low, medium or high levels of risk. MPAs were assigned to these levels depending on the extent to which they overlapped areas with different risks.

Database on coral reefs of the world

Data on coral reef locations and extents were obtained from the Millennium Coral reef Mapping project (S9), which uses high resolution Landsat satellite images to consistently map coral reef areas worldwide. This database was complemented with the UNEP-WCMC database, which provides coral reef locations from a large number of sources and maps. In combination, they provide the most current and comprehensive information available of coral reef areas worldwide.

Calculation of overall conservation status

Overall conservation status was calculated for each MPA as a weighted average of the scores in its different attributes. We generated this weighting to give more importance to certain MPA attributes. A key aspect of the recommended 2003 World Parks Congress target is the protection of biodiversity in no-take areas (the so-called reserves) because harvesting compromises the protection of biodiversity. Thus we gave most weight to “regulations on extraction”. The extent of protection of MPAs will only depend on compliance and therefore, poaching was weighted second. The control of risks that originate outside the boundaries of MPAs, but that affect their effectiveness, should be included within the management plans of MPAs. Realistically, however, such risks can only be controlled using a wider set of conservation strategies and involving different governmental instruments. Although controlling such risks can be beyond the power of most MPAs managers, these risks can have potentially severe effects on MPA effectiveness and therefore we gave an intermediate rank to this MPA attribute. By default the remaining two attributes (i.e. MPA size and Isolation) were ranked last. To this one also needs to add that, although several reports suggest that MPAs should have a

minimum size and isolation, in many cases these attributes cannot be controlled due to the distribution of reefs.

Data on MPA size and isolation were categorized into four groups each. The limits of the different categories were chosen within intervals discussed in the text as meaningful to the protection of adult neighbourhoods and propagule dispersal. The categories for MPA size were (i) $<1 \text{ km}^2$, (ii) 1 to 5 km^2 , (iii) 5 to 10 km^2 , and (iv) $>10 \text{ km}^2$. The categories for MPA isolation were (i) $<10 \text{ km}$, (ii) 10 to 20 km, (iii) 20 to 30 km, and (iv) $>30 \text{ km}$. The scores for the different attributes were transformed to numbers [i.e. 1, 2, 3, or 4; following the order of quality of the scores (i.e. from bad to good)]. The number representing the score was divided by the number of possible scores in the attribute. Here the smaller the fraction was the worse the score was. The fractions were weighted following the rank of importance discussed above (from more to less weighted): 5, regulations on extraction; 4, poaching; 3, external risks; 2, MPA size; and 1, MPA isolation. Once weighted the fractions were added to generate an average that indicates the overall conservation status of the MPA. Here the smaller the average the worse the combination of attributes was.

For simplicity, the resulting averages were categorized into four groups determined by the quartiles of the frequency distribution of the weighted averages resulting from combining all the analyzed attributes and their possible scores. The upper quartile contained mostly no-take MPAs with no to low levels of poaching, low to medium risk, mostly within the three largest MPA size categories, and varied in isolation. The MPAs with averages in this quartile were defined as having adequate conservation status. The lower quartile contained MPAs with the opposite qualities, which were defined as MPAs with very limited conservation status. The quartiles between those extremes defined MPAs with partial and limited conservation status, respectively.

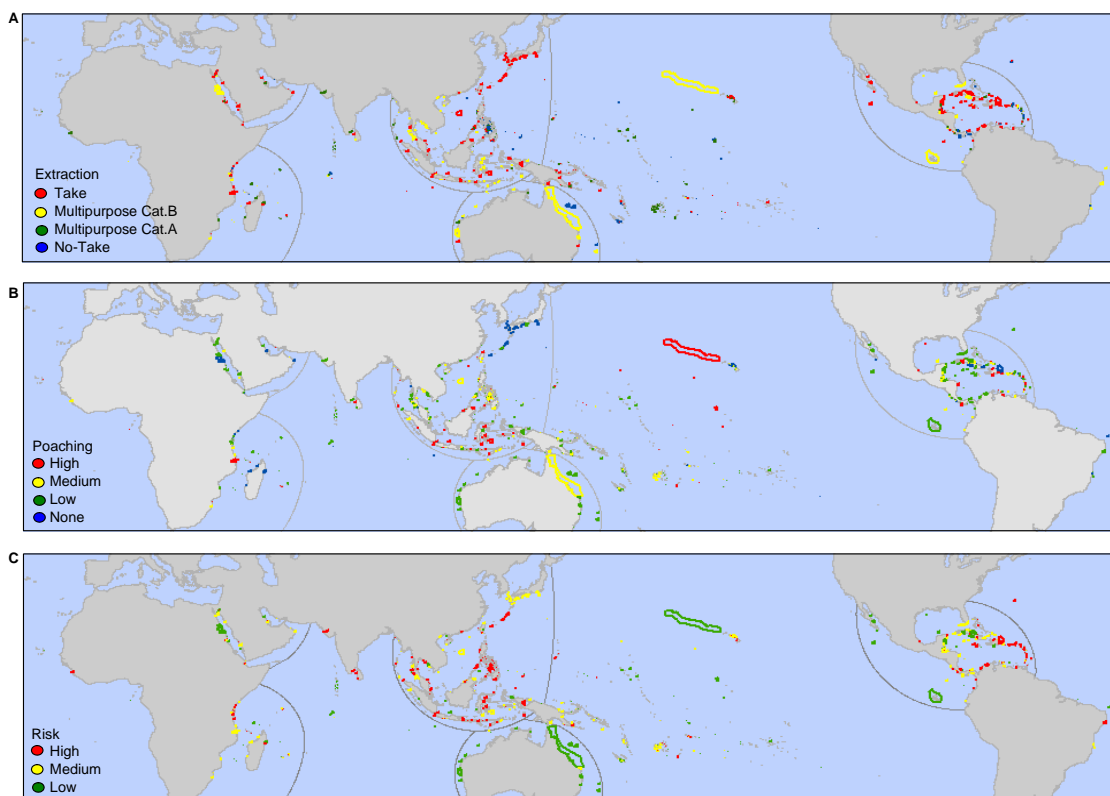


Fig. S1. The global network of coral reef MPAs classified according to regulations on extraction (A) and levels of poaching (B) and risks from external threats (C).

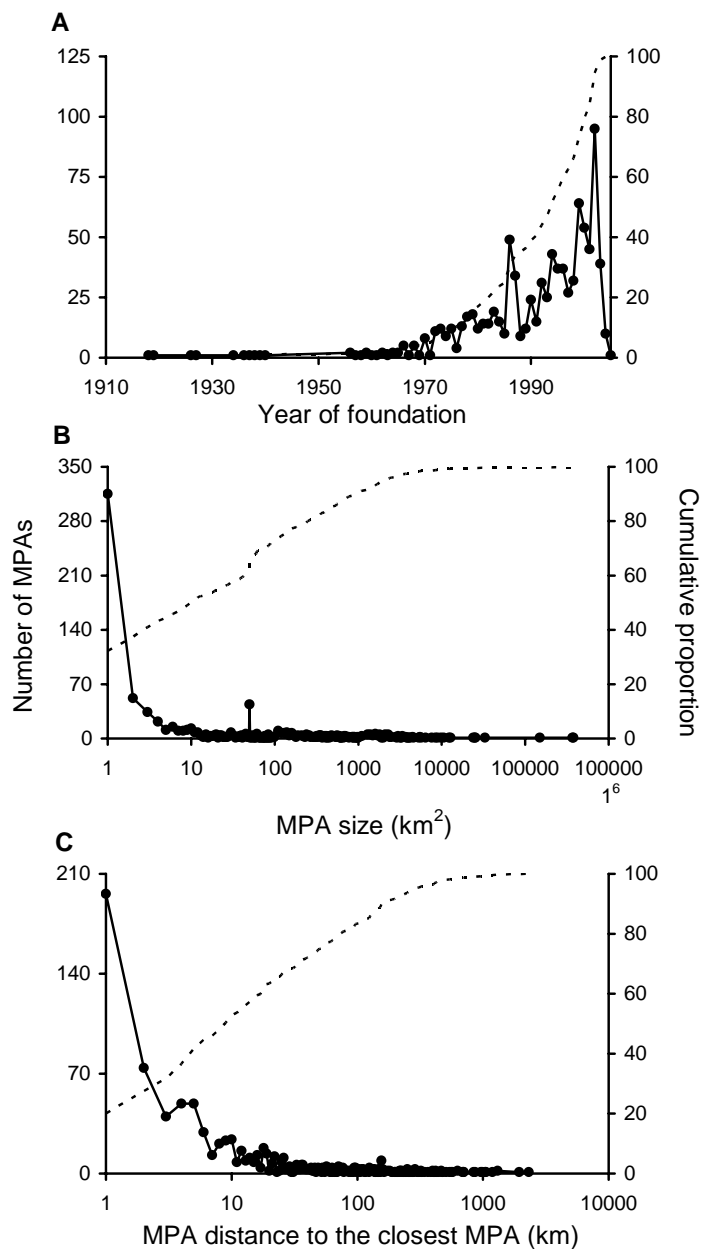


Fig. S2. Temporal pattern of creation (**A**), variation in size (**B**) and isolation (**C**) of the areas in the global network of coral reef MPAs. Points in the different graphs indicate the quantity of MPAs and are linked to the left-hand axes. Broken lines represent cumulative proportions and are linked to the right-hand axes. Plot (**A**) contains data only on 906 MPAs for which data on the year of establishment were available. Isolation was measured as the great circle route (in km) from the boundary of any MPA to its nearest neighboring MPA.

Table S1. Characteristics of regional and global MPA networks and their extent and gaps of coverage of regional and global coral reefs according to different criteria. The size and isolation of MPAs are given as averages. Coverage of reefs is given as the percent of coral reefs covered by the MPAs in each region and globally. Coverage gaps were calculated as the additional number of MPAs required to cover 30% of the coral reefs in the region or globally, based on the average area of coral reefs inside MPAs. The number of MPAs required for an optimum network was determined as the number of MPAs, with a size 10 km² and spaced 15 km from one another, require to fill the area of coral reefs not covered by existing MPAs. Mult. A and Mult. B indicate multipurpose MPAs with and without restrictions to commercial fishing, respectively.

	CHARACTERISTICS			COVERAGE OF REEFS														COVERAGE GAPS		
	Number	Size (km ²)	Isolation (km)	Partitioned by regulations to extraction				Partitioned by poaching				Partitioned by risk			Partitioned by overall status				# Missing MPAs	
				Take	Mult. B	Mult. A	No-take	High	Medium	Low	None	High	Medium	Low	Very limited	Limited	Partial	Adequate	To 30%	To optimum
Atlantic Ocean	42	245	172	5.1	12.9	0.6	0.3	0.7	0.6	17.3	0.3	8.9	8.3	1.7	0.1	9.2	9.3	0.3	25	19
Australia	23	18500	135	0.6	61.0	0.1	8.0	0.0	59.9	9.8	0.0	0.0	0.7	69.1	0.0	1.2	60.0	8.5	0	120
Caribbean	219	497	32	10.3	8.9	1.0	0.5	2.9	2.6	10.5	4.8	8.1	10.0	2.6	4.0	7.3	8.7	0.7	98	332
Eastern Pacific	24	6899	169	9.2	3.4	4.3	4.9	3.0	4.3	13.5	1.0	4.7	10.7	6.4	3.6	8.7	6.2	3.3	9	10
Indian Ocean	37	87	93	0.6	0.3	0.9	0.9	0.0	0.0	2.1	0.5	0.6	0.3	1.7	0.0	0.3	0.8	1.5	385	142
Middle East	29	1972	63	7.6	10.2	0.2	0.1	0.0	4.2	5.9	8.0	0.2	7.2	10.7	3.9	2.9	3.6	7.7	19	151
Pacific Ocean	192	2083	74	1.1	5.0	1.7	0.4	5.1	0.9	1.6	0.6	0.2	1.5	6.6	0.4	5.2	1.1	1.6	506	665
South East Asia	355	363	49	9.4	1.8	0.3	0.6	3.6	5.9	2.4	0.2	4.1	7.7	0.3	9.3	1.5	1.1	0.1	529	997
West Indian	59	426	72	3.6	2.9	3.1	0.3	1.7	2.5	2.9	2.9	4.0	5.5	0.5	4.6	1.6	0.9	2.7	119	123
Global	980	1352	63	5.3	11.1	1.0	1.4	2.9	9.3	4.9	1.6	2.9	5.0	10.8	3.6	3.6	9.4	2.1	591	2559

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