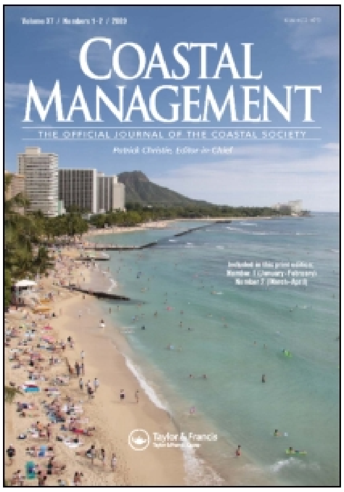

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Marine Protected Area Costs as "Beneficial" Fisheries Subsidies: A Global Evaluation

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Marine Protected Area Costs as "Beneficial" Fisheries Subsidies: A Global Evaluation

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*Marine protected areas (MPAs) are now generally accepted as important tools in the protection of coastal biodiversity. It is also likely that they play a positive role in enhancing fisheries. Yet currently, less than 1% of the global oceans are protected, although international agreements have targets ranging from 10–30% coverage. Despite its minuscule size, we consider the current MPA "network" to be beneficial to fisheries, and its running or maintenance cost, therefore, to be a positive contribution to the sustainability of fisheries, or a "beneficial" subsidy ("harmful" subsidies enhance fishing capacity and effort). A method was derived from data in Balmford et al. (*PNAS, *101: 9694–9697) to estimate the annual cost of maintaining MPAs as a function of their size, and of the degree of development of the country in question. We provide national costs of the 53 countries that jointly contribute 95% of global fisheries catch and, assuming that this type of subsidy, in a given country, cannot exceed 15% of the ex-vessel value of its fisheries catches, estimated a global MPA subsidy to fisheries of 870 million US*$*. Given that total subsidies to fisheries currently range from 30–34 billion US*$* annually (without MPA costs), this amounts to only 2.5–2.8% of total subsidies to fisheries being devoted explicitly to the maintenance of the biodiversity that sustains them.*

Keywords global fisheries, marine protected area, running cost, subsidies

Introduction

There has been debate in the past over whether or not marine protected areas (MPAs) are indeed effective as coastal marine management tools (Agardy et al., 2003; Jameson et al., 2002; Tupper, 2002). While it is likely that certain species will benefit more from MPAs than others—that is, less mobile species (Kramer & Chapman, 1999)—today, MPAs are generally accepted as necessary components of ocean conservation. Occurring typically in coastal waters (Wood et al., 2008), MPAs have many benefits, including enhancing marine biodiversity, and biomass (Halpern, 2003), and increasing ecosystem resiliency (Grafton et al., 2004; for a comprehensive list of benefits from MPAs, as well as examples, see Gell & Roberts, 2003). Therefore, various international organizations have called for extensions of their coverage, from presently less than 1%, to 10–30% of the world ocean (Wood et al., 2008). Here, however, we concentrate on the enhancement of surrounding fisheries via the spillover effect (Roberts et al., 2001; Russ et al., 2003) and as overall fishery insurance (Bohnsack, 1996), provided by the present, paltry "network" of MPAs. To the extent that

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they are often set up for the explicit purpose of, or expectation that they enhance fisheries, and because all are intended to protect the biodiversity that fisheries depend on, the setting up of MPAs can be seen as contribution to current and/or future fisheries (even when fishermen or recreational anglers oppose their creation).

Thus, the cost of maintaining MPAs (i.e., their running cost), can be considered a subsidy to fisheries, albeit a beneficial or "good" subsidy,[1] compensating, in their effect, fishing capacity-enhancing, or "bad" subsidies (see Khan et al., 2006; Sumaila et al., 2007a). According to Khan et al. (2006, 13):

> A set of fishery resources in a particular region can be viewed as a portfolio of natural capital assets capable of yielding a stream of economic benefits (both market and non-market) to society through time. If natural capital is renewable then one can within limits engage in "investment" in the natural capital assets, such as refraining from harvesting and allowing the resource to rebuild to a biological optimum. Similarly, one can also engage in "disinvestment" in the natural resource, for example, through activities such as biological and economic overfishing that take the fishery resource away from its optimal use.

Thus, subsidies are categorized into three groups, as determined by Khan et al. (2006): "good," "bad," and indeterminate or "ugly." Here, we use the terms "beneficial," "harmful," and "ambiguous," respectively, to describe the three types of subsidies. MPAs are therefore seen as "beneficial" subsidies, with any short-term loss by fishers outweighed by long-term, sustainable gains (see also Balmford et al., 2004). The benefits are highlighted in community-based fisheries, where the short-term losses (i.e., from fishing moratoria, etc.) are offset by long-term gains (Lowry et al., 2009).

This contribution is intended to estimate the running cost of MPAs globally, and to compare this with the estimated subsidies given by the world's governments to fisheries, which amount to 30–34 billions US$ (Sumaila & Pauly, 2006; Sumaila et al., 2007a). For this purpose, we use an empirical equation adapted from Balmford et al. (2004), who used their models for estimating the expected running cost of a network covering 20–30% of the world ocean.

Materials and Methods

The running costs of MPAs were evaluated from three main features, based on a questionnaire employed in Balmford et al. (2004): MPA details (e.g., total area protected and number of staff); income from MPA (e.g., sources of income and visitor fees); and spending (e.g., wages for surveillance and maintenance officers, etc.).[2] Other costs associated with MPAs, such as establishment costs, land improvements costs, or opportunity costs, are not accounted for by Balmford et al. (2004), and are therefore not considered in this study either. Therefore, our global estimate of MPA costs is probably biased downward.

The three main sources of data used for this contribution were the global database of MPAs assembled and described by Wood et al. (2008) and accessible at www.seaaroundus.org; the global fisheries catch and ex-vessel value database of the *Sea Around Us* Project (Pauly, 2007; Sumaila et al., 2007b); and an empirical equation relating running cost of MPAs to area and other information in Balmford et al. (2004).

Balmford et al. (2004) gathered their MPA cost data from approximately 500 informants working on, or otherwise connected with, 83 MPAs, that is,

> 12 from Africa, 12 from Asia, 10 from Australasia and Oceania, 13 from Europe, 13 from Latin America and the Caribbean, and 23 from North America, and ranging in size from <0.1 km^2 to >300,000 km^2. As well as encompassing a broad geographic and size range [their] sample included a wide spectrum of management types (run by government agencies, nongovernmental organizations, and local communities; zoned and not zoned), objectives (e.g., biodiversity protection, recreation, conflict reduction, and fishery enhancement), and resources protected (e.g., coral reefs, whales, and coastal scenery). Of the 76 MPAs that reported their purpose, 75 (98.7%) listed habitat and species protection (the remaining MPA was solely for research), and protection was the primary purpose for 58 (76.5%). (Balmford et al., 2004, 9694)

Thus, they concluded that their sample was "broadly representative of the range of MPAs in use worldwide (Kelleher et al., 1995) and should produce a meaningful approximation of the costs of running a global MPA system" (Balmford et al., 2004, 9694).

However, there was one caveat: "...questionnaires were only distributed to MPAs for which [they] could obtain contact details, and only 16% responded; [thus, their] figures are probably biased toward relatively well managed and funded MPAs" (Balmford et al., 2004, 9694).

Balmford et al. (2004) then derived a number of multiple regression models, from which it appeared that MPA area was by far the best predictor of running cost. We used their simplest model

$$\log_{10}(C) = 5.02 - 0.8 \cdot \log_{10}(A) \qquad (1)$$

where C is the annual cost per km^2, in 2000 US$, and A the MPA area in km^2, and which explained almost 80% of the variance in the dataset ($r^2 = 0.79$). Equation (1) being logarithmic in both variables (i.e., highly nonlinear), the cost of the MPAs of a given country must be calculated for each MPA separately, then added up (rather than adding up the MPA areas beforehand, then applying Equation (1) only once). The huge differences due to this effect are illustrated in Table 1 (Cullis-Suzuki & Pauly, 2008).

Equation (1) provides us with a method for approximating the cost of MPAs for a developmentally "average" country. However, Balmford et al. (2004) do mention a difference in costs between developing and developed countries: the median cost of MPAs for

Table 1
Example showing the variation of per area costs of MPAs, which are dependent on size of MPA, from a country with four MPAs of very different sizes

MPA	Area (km^2)	Cost ($\$\cdot km^{-2}$)	Estimated total cost (US$)
Little one	2.3	54,734	123,151
Larger one	57.4	4,104	235,348
Big one	149.6	1,906	285,098
Very big one	462.1	773	357,222
Total (correct)	—	—	1,000,819
Incorrect total	671.3	573	384,931

Table 2
Derivation of correction factor (F) for adjusting the output of Equation (1) to the GDP per caput (US$·$10^3$) of countries in 2000

Country	GDP·caput^{-1}	F
I	>14.0	1.70
II	4.0–13.9	1.35
III	2.0–3.9	1.00
IV	0.8–1.9	0.65
V	<0.8	0.30

40 developing countries was stated as US$ 1,584·km^{-2}, while it was US$ 8,976·km^{-2} for 43 developed countries.

We used this information to correct the output of Equation (1) based on a two-step procedure: (i) we used the Gross Domestic Product per capita (GDP) of countries to slot them into one of five GDP classes; and (ii) we assigned to each country a GDP correction factor (F), based on the above medians and the GDP classes, and which was used to increase or reduce the initial cost estimates produced by Equation (1).

The GDP estimates used here originate from the World Bank (www.worldbank.org) and the International Monetary Fund (IMF, www.imf.org), and pertain to the year 2000. Of the 192 territorial entities that have MPAs, and that are covered here, 57 lacked GDP per capita information, mainly small island states or dependent territories. The 135 countries with GDP estimates were arranged in order of GDP per capita value, and grouped into five classes (see Table 2), with 25–29 countries per class. Given the MPA costs in developed and developing countries as stated earlier, a deviation from the mean cost (as predicted by Equation (1)) of 1.7 for developed countries and 0.3 for developing countries, was calculated (which appears justified as the number of MPAs sampled from developed and developing countries were similar—43 and 40, respectively). We then applied these multipliers to our country classes I and V, respectively, and interpolated the F-values for classes II and IV, class III having, by definition, a correction factor of 1 (i.e., we expect average costs). Table 2 presents the data involved here, and Table 3 offers an example.

The 57 countries or territories lacking GDP per capita information from the World Bank or the IMF were subsequently assigned an F-factor of 1. It should be noted that these countries or territories have few MPAs, and that any subjective bias will have a limited influence on our global cost estimate. Also, in order to allow for comparison of the costs

Table 3
Example of application of correction factor (F) for countries of varying GDPs per capita

Country	Cost (km^2)	GDP/capita (US$)	F	Total cost (US$)
Canada	83,103,071	23,220	1.70	141,275,222
Argentina	5,046,358	7,703	1.35	6,812,584
Malaysia	25,830,863	3,927	1.00	25,830,863
China	6,363,639	949	0.65	4,136,366
India	3,992,955	453	0.30	1,197,886

of MPAs in countries with small EEZs with those of countries with large EEZs, the MPA costs were divided, for each country and territory, by the ex-vessel value (in year 2000) of the fisheries catches in their EEZs, as given on the website of the *Sea Around Us* Project (see www.seaaroundus.org). The resulting dimensionless ratio is our proposed "Investment to Marine Protected Areas" index, or MPA_{inv}, expressed in percent in Table 4. In assessing which countries are performing well in terms of running costs of MPAs relative to the value of the fisheries catches, we considered an investment of 10% or more the target investment for all countries (such an investment is demonstrated by Australia—considered one of the most advanced countries in managing its marine protected areas—which has an MPA_{inv} of just over 10%).

Table 4
Estimates of the costs of running MPAs (in year 2000) as well as MPA_{inv} (Investment to Marine Protected Areas) for 53 countries jointly contributing 95% of global marine fisheries catch, and estimates for the rest of the world; countries ranked by MPA_{inv} (MPA costs are in US$·$10^3$; MPA_{inv} in %, see text)

Rank	Country	MPA cost	MPA_{inv}	Rank	Country	MPA cost	MPA_{inv}
1	Sweden	30,046	15.0	29	Indonesia	18,100	0.7
2	Germany	12,610	12.3	30	Japan	33,046	0.7
3	Australia	111,893	11.5	31	Norway	6,195	0.6
4	Denmark	21,100	8.6	32	Iran	1,647	0.5
5	UK	70,685	5.8	33	Ireland	1,971	0.5
6	Egypt	2,969	5.5	34	Morocco	1,248	0.5
7	Ukraine	1,053	4.0	35	Chile	2,005	0.4
8	Canada	141,275	3.9	36	Iceland	2,412	0.3
9	Italy	19,258	3.6	37	Russia	7,925	0.3
10	Netherlands	4,335	3.2	38	Myanmar	1,926	0.2
11	USA (All States)	119,162	3.2	39	Angola	474	0.2
12	Spain	13,780	2.7	40	Senegal	322	0.2
13	South Africa	5,226	2.5	41	Bangladesh	345	0.2
14	Thailand	3,517	2.3	42	Pakistan	391	0.1
15	Malaysia	25,831	2.1	43	Viet Nam	1,880	0.1
16	Poland	980	1.9	44	Peru	635	0.1
17	France	8,616	1.8	45	Korea (South)	2,250	0.1
18	Brazil	16,300	1.7	46	India	1,198	0.1
19	Taiwan	3,214	1.5	47	Yemen	123	0.1
20	Sri Lanka	1,743	1.2	48	China	4,136	0.0
21	Portugal	2,602	1.1	49	Faeroe Islands	0	0.0
22	Philippines	14,182	1.0	50	Ghana	0	0.0
23	New Zealand	6,375	1.0	51	Korea (North)	0	0.0
23	Argentina	6,813	0.8	52	Namibia	0	0.0
25	Latvia	216	0.8	53	Nigeria	0	0.0
26	Mexico	6,967	0.8	—	—	—	—
27	Turkey	3,262	0.8	—	**All others**	**126,108**	—
28	Ecuador	376	0.8		**Total**	**868,722**	—

For 55 countries and territories (most often with small fisheries catches and small EEZs), of which only one, Sweden, is included in Table 4, the method detailed earlier produced MPA cost estimates above 15% of the value of their fisheries catches. In such cases, MPA_{invs} were set at 15%; this corresponds to assuming that beyond this value, MPAs do not benefit fisheries. The complete data set is presented at www.seaaroundus.org, by country, under "Governance."

Results and Discussion

The results of this study are preliminary. A range of impediments were associated with this research, such as deficiencies in the underlying database of MPAs, catch values, and GDP, and the uncertainly in Equation (1) and its underlying database. Perhaps the most obvious limitation was our failure to include start-up costs in our estimate of MPA costs, although Balmford et al. (2004) suggests skepticism on its overall impact on the cost estimate. Further, our attempt to correct for GDP per capita difference between countries, and hence in the cost of their MPAs, was not optimal in any sense. (However, not performing some type of correction would have certainly led to cost overestimates in developing, and underestimates in developed, countries.) Another source of bias is that Balmford et al. (2004) considered MPAs whose total area is "at least 50% marine," whereas our study included MPA data that were 100% marine. Finally, we assume that a higher cost equates with more (and hence, better) ocean protection than lower costs. While exceptions to this will occur (a higher cost does not necessarily imply better management), the assumption itself is unavoidable, given the global nature of this study and the scant availability of data.

Still, the results are suggestive. Table 4 gives our MPA cost estimate for 53 countries that together contribute 95% of global catch (against 81% of MPA cost), and for the world. The latter estimate is nearly 870 million US$ in 2000, or about 1% of the ex-vessel value of the global fisheries catch (see Sumaila et al., 2007b), and 2.5–2.8% of total subsidies to fisheries, as total subsidies to fisheries range from 30 to 34 billion US$ annually, excluding MPA cost (Sumaila & Pauly, 2006).

Given that current MPAs cover only 0.7% of the entire ocean (Wood et al., 2008), but cost nearly 870 million US$ to maintain, one could assume that it would cost about 25–37 billion US$ annually to protect 20–30% of the global oceans. This value is higher than the 5–19 billion US$ cost estimate in Balmford et al. (2004) because it is affected by the many small, and hence relatively costly, MPAs. In the MPA database we used in this study, which is comprised of over 4,400 entries, the mean size of an MPA is 544 km^2, whereas the median is 4.6 km^2. This vast disparity between mean and median values is a result of the world's ten largest MPAs, which together make up 68% of the world's cumulative MPA area (Wood et al., 2008). In contrast, Balmford et al. (2004) based their projections on 83, generally larger MPAs.

Notably, the data generated in this study show that a number of the countries have low MPA_{inv} scores. This is in part a reflection of the dominance of small MPAs. Only three countries with large MPAs had MPA_{inv} values of over 10%: Sweden, Germany, and Australia—all developed and relatively wealthy countries.

While wealthier countries are clearly in a better position to establish MPAs than poorer ones, the results show that wealth did not necessarily dictate the MPA_{inv} score: Japan, Norway, and Iceland, all three comparatively wealthy countries and major global fishing nations, scored MPA_{invs} of only 0.3–0.7.

MPA_{inv} is, rather, a potential indicator of a country's commitment to sustainability, or more specifically, how well fishing countries score in relation to their effort to protect their fisheries and coastal biodiversity (Alder & Pauly, 2008). Although international agreements have called for up to 30% global ocean MPA coverage, these calls have remained largely unanswered. When they are, the MPA_{inv} indicator could be a useful tool in monitoring progress toward regional and global coastal targets.

To achieve current targets, the overwhelming majority of coastal countries will have to expand on their existing MPAs (if any). Our contribution suggests that this can be done in cost-effective fashion by creating fewer large MPAs, rather than many small ones. Indeed, if this were to occur, our global estimates of the costs of maintaining 20–30% of global oceans under protection would be reduced. This is in line with recent ecological studies encouraging the establishment of effective, larger MPAs, or MPA networks (Mora et al., 2006; Walters, 2000). However, it must be noted that the costs and benefits of MPAs will not increase indefinitely with their size: ultimately, there will be a point where MPAs become so large that they cause more problems than they resolve (see Roberts et al., 2005).

Conclusion

In this study, we have stressed that MPAs are only part of the solution toward ocean and fisheries conservation. Also, we have seen that MPAs, although beneficial in the long term, generate costs, and the question becomes how to sustain them, especially in the case of developing countries, even though they are cheaper to run than those in developed countries (see Results). By converting jobs from the fisheries sector into various MPA management positions, some of the financial stress could be reduced (Gell & Roberts, 2003). In addition, notably in developing countries, networks of MPAs have the potential to reduce costs (Lowry et al., 2009), as do co-management arrangements (Kuperan et al., 2008) and inter-municipal associations fostering Ecosystem Based Management approaches (Eisma-Osorio et al., 2009).

As stated earlier, MPAs can be but one of the tools used in fisheries and ocean management. Indeed, while the ecological benefits of MPAs are widely understood, many of their social impacts are conflicting and require further study (Christie, 2004; Gell & Roberts, 2003). However, recognizing that MPAs are, at any rate, part of the solution, we propose here that subsidies to fisheries should be considered with global MPA costs in mind, particularly as currently, on a global scale, they represent less than 3% of fishing subsidies. We are encouraged in this by the outgoing U.S. administration's recent creation of large MPAs[3] in the Pacific.

Notes

1. Arguably, "beneficial" subsidies could fall under categories other than fisheries (i.e., biodiversity or environment sectors). Perhaps in the future, subsidies could be divided up between relevant sectors and the cost shared among them. However, because of the infinite difficulties involved with "partitioning out" the costs, it is appropriate to label them here as fisheries subsidies, as they contribute to the overall, long-term benefit of the fishing sector.
2. See www.pnas.org for supplementary text detailing running costs in Balmford et al. (2004).
3. This study does not account for these new MPAs, which would not change any of its conclusions.

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