Marine Policy 35 (2011) 1–9

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Understanding the cost of establishing marine protected areas

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ARTICLE INFO

Article history:
Received 11 June 2010
Accepted 15 July 2010

Keywords:
Marine protected area (MPA)
Reserve
Cost
Establishment
Conservation
Management

ABSTRACT

While the recurrent cost of managing marine protected areas (MPAs) has been documented and estimated, there has been virtually no attempt to quantify the cost of establishing MPAs in the first place. This lack of attention is likely the result of the complexity of the process, involving often uncoordinated efforts of a multitude of governmental and non-governmental entities over a protracted period of time with no clear start and end-point. Using information gathered from a representative subset of MPAs worldwide, this paper presents the first attempt to identify and describe the various components, and explore potential predictors of the total funds spent in the course of establishment. The thirteen MPAs studied vary in size (from <1 to $>360{,}000\ km^2$), location (including near- and offshore in both developed and developing countries), objectives and degree of protection. Variation in MPA start-up costs is shown to be most significantly related to both MPA size and the duration of the establishment phase. Development of a method to estimate the potential cost of establishing proposed MPAs should play a crucial role in the conservation planning process.

1. Introduction

The growing number of marine protected areas (MPAs) worldwide, increasing at approximately 5% annually [1], reflects recognition of their utility as an integral component of initiatives to conserve marine biodiversity and fisheries resources [2]. MPA research has historically focused on potential population- and ecosystem-scale benefits (e.g., increased biomass, spillover, larval export of protected species, reduced habitat loss) as well as potential, resultant economic benefits. However, practical conservation planning strategies also require a comprehensive understanding of the costs of MPA establishment. According to Naidoo et al. [3], "by ignoring the cost side of conservation planning, ecologists and conservation biologists are missing great opportunities to achieve more efficiently conservation objectives in a world of limited conservation resources."

While socio-economic opportunity costs (as well as benefits) of MPAs to various stakeholder groups have received some consideration [4–7], investigations of the direct financial costs of MPAs are rare, especially in the peer-reviewed literature. The financial cost of an MPA includes the initial, typically short-term investments in establishment as well as the recurrent costs of maintenance (including administration, management and enforcement) incurred over the long-term. Balmford et al. [8] developed a model to predict total running (i.e., maintenance) costs per unit area based on a survey of 83 MPAs worldwide. Using a similar survey, Gravestock et al. [9] examined the income necessary for an MPA to achieve its management objectives. In addition, Cullis-Suzuki and Pauly [10] applied the Balmford et al. [8] model to estimate the annual maintenance cost of the current global network of MPAs, and ranked the maritime countries of the world according to their financial investment in MPAs. In contrast, a search for studies regarding establishment costs produces only one peer-reviewed study [11], which provides a detailed analysis of the establishment and maintenance costs for six MPAs in the Philippines.

Examination of the issues surrounding MPA establishment yields clues regarding the scarcity of this topic in the literature. First, the duration of the establishment phase is difficult to define and can vary substantially between MPAs. Theoretically, it begins with the idea that a particular location deserves protection, and ends sometime after the official designation of the MPA. Funding for planning and development during this period is typically derived from multiple sources located within and/or outside of the host country, including governments, non-governmental organizations (NGOs), private individuals and corporations. Additionally, the establishment phase precedes the formation of the dedicated management entity usually responsible for the maintenance of financial records. Instead, existing records of monetary, as well as volunteer and in-kind contributions to the establishment process are likely to be spread across various funding entities. Finally, institutional memory tends to be limited, and

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doi:10.1016/j.marpol.2010.07.001

the likelihood that financial records will be lost increases over time. In contrast, data quantifying the routine cost of maintaining an established MPA may be derived from annual budgetary information, and this collective spending is typically administered by a single management entity. Furthermore, the establishment of MPAs is not directly comparable to the creation of terrestrial protected areas for which more financial data may exist. For example, MPAs rarely require the purchase of land, which may represent the largest component of the cost of establishing terrestrial protected areas [12].

In order to understand and quantify the total financial cost of an existing or proposed MPA in a typically data-limited environment, it is necessary to derive a method for estimating not only routine maintenance costs, but also initial establishment costs. This study presents a first attempt to estimate the latter. Financial data were gathered for 13 MPAs worldwide, ranging in size from <1 to $>360{,}000\ km^2$, located within both developed and developing countries. For each MPA, the total cost of establishment was evaluated according to funding sources and categories of spending. Potential predictors of total establishment cost were explored, including, most significantly, the duration of the establishment phase and the size of the MPA.

2. Assumptions and data

For each MPA included in this study, the establishment phase was assumed to begin prior to formal designation, and included the stages of proposal, planning and preparation for the implementation and enforcement of management objectives and regulations. The end of the establishment phase was assumed to coincide with the availability of income to cover the routine costs of MPA administration, management, and enforcement. Depending on the particular MPA, this income may be derived from revenue from financial self-sufficiency programs (including visitor fees) and/or regular budgetary allocation from a national or local management authority. Establishment spending was assumed to include the costs associated with project proposal, development of a legal framework for designation, development of a management plan, outreach to local community and stakeholder groups, community and stakeholder compensation schemes (including alternative-income generating activities and fisher buy-out), ecological and socio-economic research, management and enforcement training, and infrastructure (including buildings, equipment, and site delineation). Contributors of establishment phase funding were divided into categories according to location (multilateral, bilateral, national, and sub-national) and type (government, NGO, private individual, and volunteer and in-kind donations).

As a starting point for advancing current knowledge of the cost of establishing an MPA, data for a representative sample of 13 MPAs was gathered from the peer-reviewed literature, financial and budgetary documents in the gray literature, and personal communication with funding agencies and MPA managers (Table 1). These MPAs are located within the exclusive

Table 1
Description of MPAs evaluated in this study, including the sources of financial data regarding establishment costs.

Site	Country	Year[a]	Area (km^2)	No-take[b]	Establishment time (years)	Sources
1. Bibilik MPA	Philippines	2003	0.2	1.00	3.0	Butardo-Toribio et al. [11], M. Butardo-Toribio (pers comm., USAID/EcoGov2, 03/10)
2. Talisay MPA	Philippines	2004	0.3	0.60	1.5	Butardo-Toribio et al. [11], M. Butardo-Toribio (pers comm., USAID/EcoGov2, 03/10)
3. CHICOP	Tanzania	1994	0.5	1.00	8.0	Soley [24], Neckenig [25], Riedmiller [15,16], S. Riedmiller (pers comm., CHICOP,03/10)
4. Villahermosa MS	Philippines	2004	0.7	0.43	2.5	Butardo-Toribio et al. [11], M. Butardo-Toribio (pers comm., USAID/EcoGov2, 03/10)
5. Tambunan MPA	Philippines	2003	1.0	1.00	2.0	Butardo-Toribio et al. [11], M. Butardo-Toribio (pers comm., USAID/EcoGov2, 03/10)
6. MISSTA MPA	Philippines	2003	1.6	1.00	2.0	Butardo-Toribio et al. [11], M. Butardo-Toribio (pers comm., USAID/EcoGov2, 03/10)
7. Pilar MPA	Philippines	2005	1.8	0.17	1.0	Butardo-Toribio et al. [11], M. Butardo-Toribio (pers comm., USAID/EcoGov2, 03/10)
8. Saba MP	Netherland Antilles	1987	8.7	0.15	6.0	Walker [19], S. White (pers comm., USFWS, 03/10)
9. Bonaire NMP	Netherland Antilles	1984	27	0.15	9.0	Dixon et al. [18], De Meyer & MacRae [17]
10. Nha Trang Bay MPA	Vietnam	2001	160	0.10	5.0	GEF [20], B. O'Callaghan (pers comm., IUCN, 03/10)
11. Seaflower MPA	Colombia	2005	65,018	0.04	9.5	CORALINA [21], Killmer et al. [22]
12. Mariana Trench MNM	USA	2009	246,608	0.00	6.0	H. Bradner (pers comm, PEG, 01/10), anon pers comm.
13. PMNM	USA	2006	362,100	1.00	9.0	S. Ganey (pers comm, PEG, 01/10), anon pers comm.

[a] Year of official designation.
[b] Proportion of total marine area.

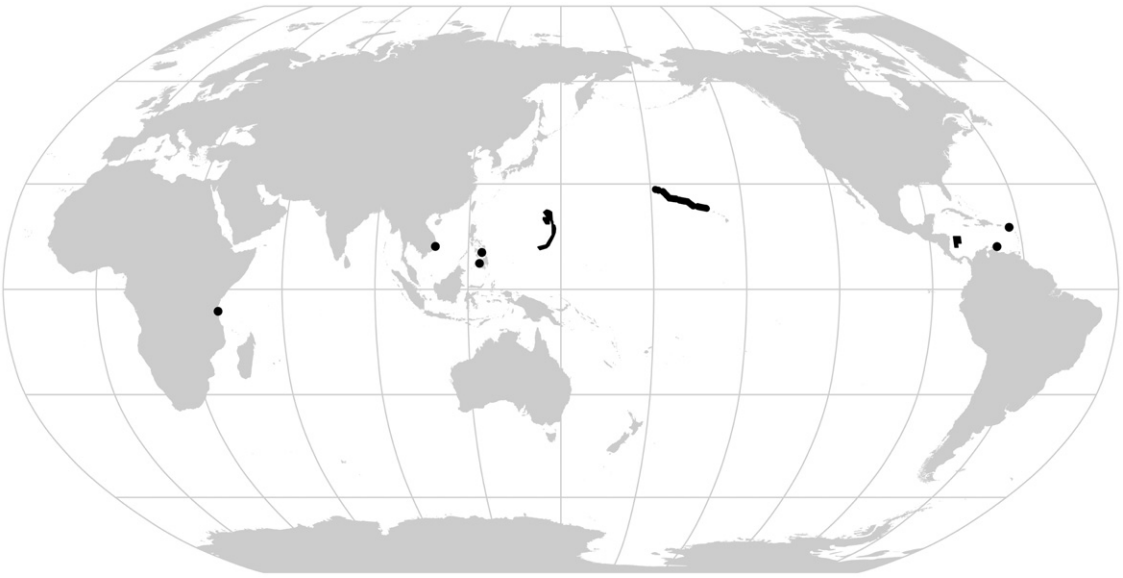

Fig. 1. Map of MPAs included in this study. The extent of the three largest MPAs (Papahānamokuākea MNM, Marianas Trench MNM, and Seaflower MPA) are depicted here, while all other MPAs are indicated as points (•). The Philippine MPAs are indicated by two points, one representing two MPAs located in the Camotes Sea and one representing four MPAs located in Illana Bay.

Table 2
Approximate total establishment cost and total establishment cost per unit area, including purchasing power parity (PPP)-adjusted values, calculated according to data gathered from various sources.

Site	Total establishment cost		PPP-adjusted Total establishment cost	
	(2005 USD)	(2005 USD· km^{-2})	(2005 USD)	(2005 USD· km^{-2})
1. Bibilik MPA	20,518	102,591	8,002	40,011
2. Talisay MPA	7,528	22,950	2,936	8,950
3. CHICOP	1,583,455	3,192,450	554,209	1,117,358
4. Villahermosa MS	8,179	11,802	3,190	4,603
5. Tambunan MPA	18,198	17,668	7,097	6,891
6. MISSTA MPA	16,040	10,025	6,256	3,910
7. Pilar MPA	8,212	4,578	3,203	1,785
8. Saba MP	557,237	64,050	624,106	71,736
9. Bonaire NMP	1,145,058	42,410	1,282,464	47,499
10. Nha Trang Bay MPA	2,370,832	14,818	711,250	4,445
11. Seaflower MPA	14,795,169	228	7,545,536	116
12. Mariana Trench MNM	10,000,000	41	10,000,000	41
13. PMNM	34,800,000	96	34,800,000	96

economic zone (EEZ) of countries characterized by a very high human development index (HDI) (i.e., the Netherland Antilles and the United States), high HDI (i.e., Colombia) and medium HDI (i.e., the Philippines, Vietnam, and Tanzania) [13] (Fig. 1). Formally designated between 1984 and 2009, the MPAs were chosen for inclusion in this study based on the availability of data. Their size spans seven orders of magnitude (approximately 0.2–362,100 km^2; median = 1.8 km^2, mean = 51,841 km^2), and they vary from fully protected no-take reserves to those allowing limited fishing activities. For each of these 13 MPAs, the total cost of establishment is reported in 2005 USD, estimated according to the market exchange rate[1] (Table 2). Total establishment costs were also adjusted to account for purchasing power parity (PPP),[2] an indicator of the local 'value' of one U.S. dollar. Additionally, the amount of funding (either monetary or in the form of volunteer labor and in-kind donations) contributed by various entities located either within or outside of the host county was identified for each MPA (Table 3). (The value of volunteer labor was estimated according to the total volunteer time multiplied times an appropriate wage, and in-kind donations were estimated according to the monetary value of goods and/or services contributed.)

3. Results

A detailed description of each MPA is provided in Appendix A. Establishment of the smallest MPA included in this study, Bibilik, located in the Philippines, is characterized by the lowest total cost ($20,518; 2005 USD) incurred over the course of three years. In contrast, the largest MPA in the sample, Papahanamokuakea MNM in the Northwestern Hawaiian Islands, was also the most expensive to establish ($34.8 million; 2005 USD), and this spending was spread over nine years. When evaluated per unit area, establishment of Bibilik MPA cost $102,591 per km^2 while Papahanamokuakea MNM required only $96 per km^2. Thus, initial

[1] http://fx.sauder.ubc.ca.
[2] World Bank. World Development Indicators. Washington, D.C.; 2008.

Table 3
Proportional contribution to total establishment cost according to relative location and type of funding source.

Site	Multilateral	Bilateral				National				Sub-national			
	Gov.	Gov.	NGO	Priv.	Vol.	Gov.	NGO	Priv.	Vol.	Gov.	NGO	Priv.	Vol.
1. Bibilik MPA	–	0.32	–	–	–	< 0.01	–	–	–	0.65	–	–	0.02
2. Talisay MPA	–	0.83	–	–	–	–	–	–	–	0.02	–	–	0.15
3. CHICOP	< 0.01	0.26	< 0.01	0.49	0.24	–	–	–	–	–	–	–	–
4. Villahermosa MS	–	0.44	–	–	–	–	–	–	–	0.42	–	–	0.13
5. Tambunan MPA	–	0.24	–	–	–	0.01	–	–	–	0.65	0.07	0.02	< 0.01
6. MISSTA MPA	–	0.31	–	–	–	–	–	–	–	0.69	–	–	–
7. Pilar MPA	–	0.23	–	–	–	–	0.25	–	0.03	0.47	–	0.02	–
8. Saba MP	–	–	–	–	–	0.69	0.21	–	–	0.1	–	–	–
10. Nha Trang Bay MPA	0.52	0.38	–	–	–	0.06	–	–	–	–	–	–	0.05
11. Seaflower MPA	0.33	0.01	0.11	–	–	0.01	0.02	–	0.06	0.19	< 0.01	–	0.26
12. Mariana Trench MNM	–	–	–	–	–	0.91	0.06	–	–	–	0.03	–	–
13. PMNM	–	–	–	–	–	0.95	0.04	–	–	–	0.01	–	–
Mean	0.07	0.27	0.01	0.04	0.02	0.24	0.05	0.00	0.01	0.27	0.01	0.00	0.06
Median	0.00	0.26	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.15	0.00	0.00	0.01

Gov.: Government. NGO: Non-governmental organization. Priv.: Private individual. Vol.: Volunteer labor and/or in-kind donation.
(Note that Bonaire NMP is not included due to lack of data.)

Table 4
Regression parameters for models predicting variation in total establishment cost as a function of MPA size and duration of establishment phase.

Model	Dependent variable (log; 2005 USD)	Intercept	Independent variables						r^2
			MPA size (log; km^2)			Establishment time (years)			
			Slope	*F*	*P*	Slope	*F*	*P*	
A	**Establishment cost**	4.66	0.52	33.1	< 0.001	–	–	–	0.75
B	**Establishment cost**	3.45	–	–	–	0.40	51.5	< 0.001	0.82
C	**Establishment cost**	3.73	0.26	19.8[a]	$0.01 < P < 0.001$[a]	0.28	139.3[a]	< 0.001[a]	0.94
D	**Establishment cost/area (km^2)**	4.66	−0.48	27.8	< 0.001	–	–	–	0.72
E	**PPP-adjusted establishment cost**	4.30	0.57	35.1	< 0.001	–	–	–	0.76
F	**PPP-adjusted establishment cost**	2.97	–	–	–	0.44	54.8	< 0.001	0.83
G	**PPP-adjusted establishment cost**	3.28	0.29	24.2[a]	< 0.001[a]	0.31	168.7	< 0.001[a]	0.95
H	**PPP-adjusted establishment cost/area (km^2)**	4.30	−0.43	19.2	< 0.001	–	–	–	0.64

PPP: purchasing power parity.

[a] Values derived from partial-*F* test.

investigation of trends in the data suggested that variation in total establishment cost is correlated to MPA size and the duration of the establishment phase (i.e., establishment time). Regression analyses were consequently performed in order to evaluate these potential predictors (Table 4).

Estimates of the total cost of establishment and approximate area of each MPA were $\log_{10}$-transformed in order to correct for non-normality. A significant, positive linear relationship was determined to exist between total establishment cost ($\log_{10}$; 2005 USD) and MPA size ($\log_{10}$; km^2), (model A, Table 4; Fig. 2a). Establishment time (measured in years) was also a significant predictor of the total establishment cost (model B, Table 4; Fig. 2b). When evaluated individually, MPA size accounted for 75% of the variation in total establishment cost, while establishment time explained 82% of the total variation. Furthermore, Model B was significantly improved following the addition of MPA area (Model C, Table 4; Fig. 2d). In fact, the combination of establishment time and MPA size in a multivariate model explained 94% of the variation in total establishment cost. Alternatively, the inclusion of MPA area in Model B marginally reduced the variation in total establishment cost by 12% (i.e., partial $r^2 = 0.12$).

The statistical relationship between total establishment cost per unit area ($\log_{10}$; 2005 USD $\cdot$ km^{-2}) and MPA size (km^2) was also evaluated. Fig. 2c indicates that large MPAs were less expensive to establish per unit area relative to smaller MPAs, and a regression analysis reveals the significance of this inverse relationship (model D, Table 4). This result is not surprising given the potential for economies of scale. However, the underlying one-to-one, inverse correspondence between the log of a variable (e.g., area) and the log of its inverse (e.g., 1/area) artificially increases the strength of the statistical relationship between log-transformed area and cost per unit area.

The total cost of establishment for each MPA included in this study was adjusted according to purchasing power parity (PPP) using the ratio of the PPP conversion factor to the market exchange rate (corresponding to 2005). Modified values are listed in Table 2. The effect of this conversion was to reduce the estimated cost for MPAs located in countries where the U.S. dollar has a greater value (i.e., purchasing power) relative to the official exchange rate of the foreign currency, and to increase the estimated cost for MPAs in countries where the local currency is stronger than the dollar. Overall, adjustment according to PPP may be interpreted as standardization to remove the effect of relative variation in economies. The strength of the relationship between the PPP-adjusted total establishment cost and the independent variables, MPA area and establishment time, was evaluated. Regression analyses indicate that this adjustment resulted in a slight increase in the significance of the relationship with both MPA area and establishment time (models E & F, Table 4). Consideration of PPP resulted in a similar improvement in the fit of the multivariate model to the data (model G, Table 4).

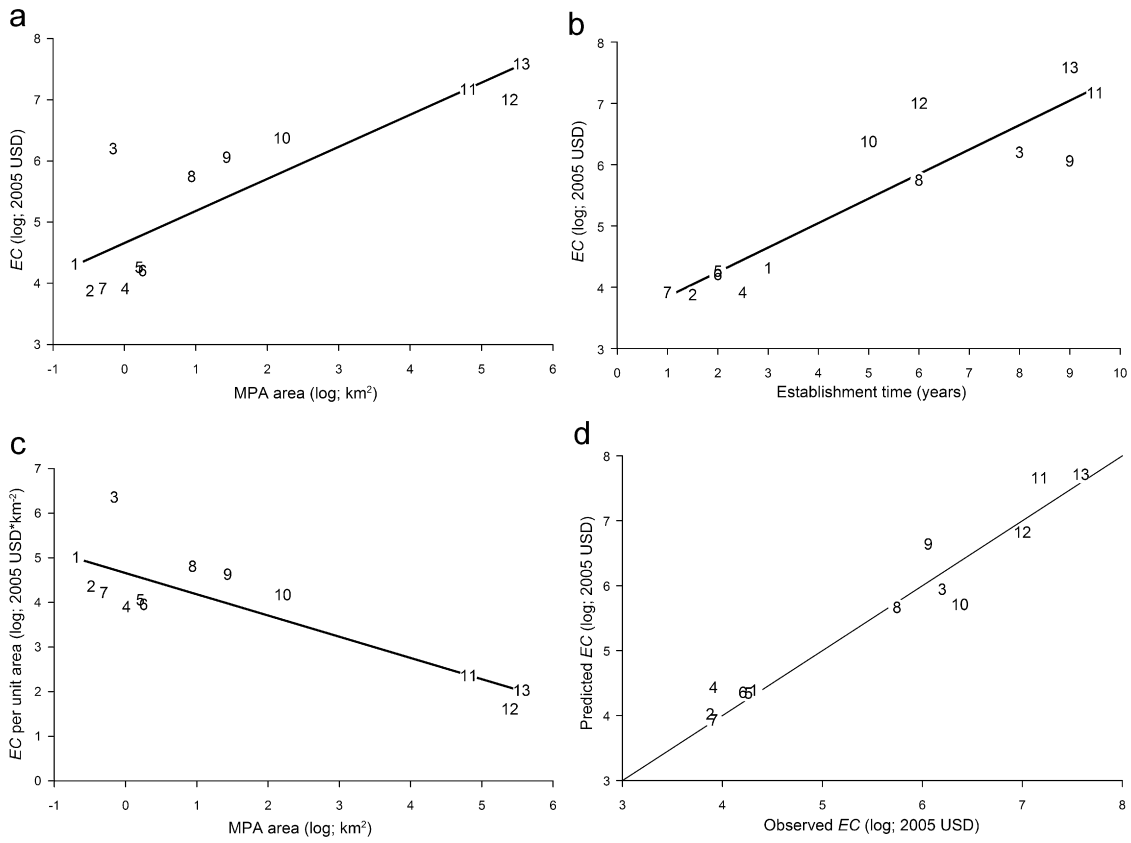

Fig. 2. Results of regression analyses demonstrating the relationship between: (a) total establishment cost (*EC*) and MPA area (Model A); (b) EC and the duration of the establishment phase (years) (Model B); (c) EC per unit area and MPA area (Model D); (d) observed and predicted values of EC using the multivariate model (C).

In contrast, adjustment according to PPP had an adverse effect on the strength of the relationship between total establishment cost per unit area and MPA area (model H, Table 4).

Evaluation of Table 3 enables insight into overall patterns in the source of establishment cost funding. Overall, the majority of funding for each MPA included in this study was contributed by governmental entities. For the MPAs located within the EEZ of countries with a very high HDI (i.e., Saba Marine Park, Mariana Trench Marine National Monument, and Papahānamokuākea Marine National Monument), the majority of funding was contributed by governmental agencies operating at the national level. In contrast, those MPAs located in the EEZ of less developed countries (i.e. Bibilik MPA, Talisay MPA, Chumbe Island Coral Park, Villahermosa Marine Sanctuary, Tambunan MPA, MISSTA MPA, Pilar Municipal Marine Park, Nha Trang Bay MPA, and Seaflower MPA) derived the majority of establishment phase funds from governmental agencies located either outside of the host country and/or from those operating at the sub-national level. Additionally, volunteer labor and in-kind donations, primarily from sub-national community groups, was a component of contributions to the establishment phase of all but three of the MPAs considered here. Note that the relative importance of sub-national support is largely due to the over-representation of locally created Philippine MPAs in the data set.

4. Discussion

While the results of this study provide valuable information regarding the estimation of the total cost of establishing a variety of MPAs worldwide, analyses were limited by the small sample size. The low number of MPAs included in this study reflects an extreme paucity of available financial data. Here, data were primarily derived from the peer-reviewed and gray literature, supplemented by personal communications. Indeed, for two MPAs (Papahānamokuākea and Mariana Trench MNMs), the literature provided no information on establishment costs, and estimates relied entirely on personal communication and/or access to institutional data.

Difficulties in obtaining a complete record of financial data, including all possible contributions, may have resulted in an underestimation of the total cost of MPA establishment. When gathering data via personal communication, the existence of adequate financial records as well as the willingness of all funding sources to divulge financial data was crucial. A thorough review of the available literature indicates that this constraint is likely to be applicable to most MPAs worldwide. Additionally, the financial data used in this study accounted only for 'supportive' contributions from those entities in favor of MPA establishment and not for costs covered by those opposed to the creation of an MPA. MPA creation is often not supported by all stakeholders due to factors such as the expectation of loss of fisheries revenues following the implementation of no-take regulations. Stakeholders most likely to lose revenues, especially in the short-term, may spend time and money lobbying against MPA establishment. Though not included here, it is possible to conceive of a situation where incorporation of these 'obstructive' contributions to the total cost of establishment would also be considered.

Insights gained from the MPAs evaluated here indicate important questions that deserve consideration following the compilation of a larger data set, e.g., (1) do MPAs established in developing countries cost less on average than those created in more developed countries?; (2) do MPAs created with predominately sub-national support cost less on average than MPAs established with the

financial support of national and/or foreign entities?; (3) as the number of MPAs within the EEZ of a given country increases over time, does the cost of establishing each subsequent MPA decrease due to a national rise in expertise, development of a legal framework for designation, and increased efficiency due to lessons learned from past experiences? Also, it is important to differentiate between the cost of establishing MPAs that are later judged as 'effective' and those that remain 'paper parks.'

It is important to acknowledge the fact that half of the data points in this study were derived from inherently similar Philippine MPAs. The impact of this over-representation was examined by performing regression analyses using average values of total establishment cost, MPA size, and establishment time in place of individual values for these six MPAs (i.e., Bibilik MPA, Talisay MPA, Villahermosa Marine Sanctuary, Tambunan MPA, MISSTA MPA, and Pilar Municipal Marine Park). While the relationship between total establishment cost and MPA size was consistent with previous results and remained significant (slope=0.35, $0.01<P<0.05$, $r^2=0.67$), the significance of the relationship with establishment time was considerably diminished (slope=0.21, $P>0.05$, $r^2=0.40$).

Given the results of this study, it is useful to compare the current understanding of total establishment cost to what is known regarding the routine cost of MPA maintenance. According to a study of 83 MPAs worldwide (including 3 of the MPAs considered here), Balmford et al. [5] determined that the most significant predictor of the annual maintenance (or 'running') cost per unit area was MPA size (where both variables were $\log_{10}$-transformed to correct for non-normality). While this study reported the regression results in terms of cost per unit area, redefining the relationship with MPA size in terms of total annual cost without adjusting for area yields results which are more directly comparable with those presented here. Thus, the relationship between annual cost of maintenance (MC) and the area of an MPA (a), adjusted to 2005 USD, was re-estimated as

$$\log_{10}(MC;\text{2005 USD year}^{-1}) = 5.23 + 0.21\log(a;\text{km}^2);$$
$$(F = 16.5,\ P < 0.001,\ r^2 = 0.17). \quad (1)$$

The association with area is significant. However, this variable accounts for only 17% of the variation in the sample of annual maintenance costs, indicating the existence of other, unidentified factors potentially related to maintenance cost. Confidence in the strength of conclusions regarding maintenance costs is relatively high due to the comparatively large data set. According to the results presented here (model A), MPA size was also a significant predictor of total establishment cost (EC):

$$\log_{10}(EC;\text{2005 USD}) = 4.66 + 0.52\log(a;\text{km}^2). \quad (2)$$

Mathematically, these two models are quite similar. In both cases, cost increases with MPA size, though the rate of increase in log-transformed establishment cost is slightly greater. (This discrepancy may be partially attributed to the bias resulting from the inclusion of all six Philippine MPAs.) Furthermore, MPA size explains a greater proportion of the variation in establishment cost ($r^2=0.75$) relative to annual maintenance costs. When expressed per unit area, both maintenance and establishment costs are considerably higher for smaller MPAs.

It is important to recognize the effect of log-transformation. In reality, the estimated rise in the cost of establishment and maintenance with increasing MPA size is highly nonlinear (Table 5, Fig. 3). Thus, the relationships between both annual maintenance cost and total establishment cost with area may be equivalently expressed as

$$MC = 10^{5.23}a^{0.21} \quad (3)$$

Table 5
Estimated total establishment cost (*EC*) and annual maintenance cost (*MC*) for MPAs of increasing size.

MPA size (km^2)	*EC*[a]		*MC*[b]	
	(2005 USD)	(2005 USD · km^{-2})	(2005 USD · $year^{-1}$)	(2005 USD · km^{-2} · $year^{-1}$)
0.5	31,876	63,752	146,819	293,639
5	105,551	21,110	238,113	47,623
50	349,514	6,990	386,175	7723
500	1,157,349	2,315	626,302	1,253
5000	3,832,343	766	1,015,743	203
50,000	12,690,081	254	1,647,342	33
500,000	42,020,808	84	2,671,675	5
1,000,000	60,255,959	60	3,090,295	3

[a] Estimated according to Eq. (2) or (4).
[b] Estimated according to Eq. (1) or (3).

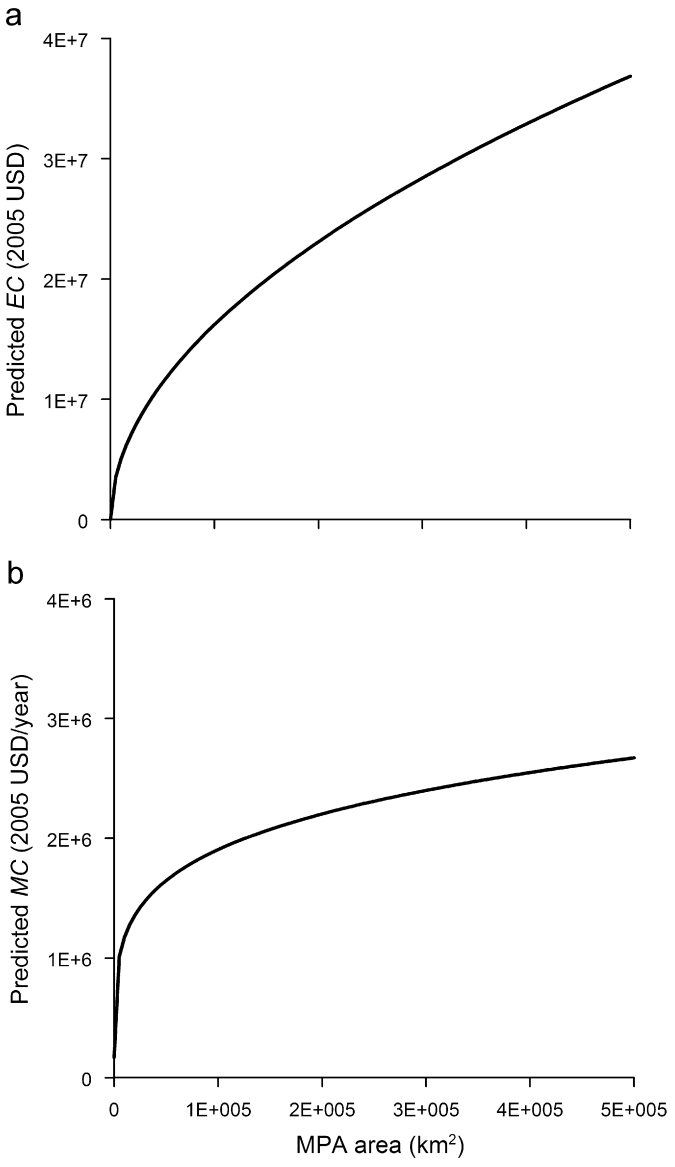

Fig. 3. Predicted nonlinear rise in total establishment cost (*EC*) and annual maintenance cost (*MC*) with increasing MPA size, estimated according to Eqs. (3) and (4), respectively.

and

$$EC = 10^{4.66} a^{0.52}. \quad (4)$$

In each case, cost is predicted to rise rapidly for each unit increase in MPA size for small MPAs, and then slow as MPA size becomes large.

Given the results listed in Table 4, the choice of model to estimate total establishment cost depends on the level of knowledge regarding a particular proposed or existing MPA and the questions being considered. Overall, the multivariate model (C),

$$\log_{10}(EC; 2005\ \text{USD}) = 3.73 + 0.28\, t(\text{years}) + 0.26 \log(a;\ \text{km}^2) \quad (5)$$

which describes the rise in total establishment cost with increasing time spent in the establishment phase (t) and MPA size and, is expected to provide the most accurate prediction of establishment cost. For example, Model C could be easily used during the proposal stages of an MPA to understand the incremental increase in anticipated establishment cost resulting from a delay in the implementation of a financial sustainability plan. Model A (Eq. (2), or equivalently, Eq. (4)) may also yield a relatively accurate estimate when only the size of the MPA is known. The similarity between Model A and the Balmford et al. (2004) model of annual maintenance costs will likely facilitate the estimation of the total financial cost (including both establishment and maintenance) of a particular MPA over its lifetime or an arbitrary period. Model B allows for estimation of the cost of establishment according to the projected duration of the establishment phase for an MPA of any size:

$$\log_{10}(EC;\ 2005\ \text{USD}) = 3.45 + 0.40\, t(\text{years}). \quad (6)$$

Finally, accounting for PPP resulted in a negligible improvement in Models A and C.

5. Conclusions

Despite the limitations associated with the data set used in this analysis, the distribution of MPAs by area and location is, to some extent, representative of the true global distribution of MPAs. According to Wood et al. [1], this global distribution is dominated by a greater abundance of relatively small MPAs, predominately located in the tropics. The objectives of the MPAs included in this study are also broad in scope (Appendix A), which is partially indicated by the variation in no-take coverage (Table 1). In addition, the countries represented in this sample span a wide range of development status. In general, the socio-economic and political issues driving the establishment processes for the MPAs described here vary widely, representing a spectrum of scenarios under which an MPA may be created.

The models developed in this study reinforce and validate intuitive expectations of the total costs incurred during the establishment phase of an MPA. While the total establishment cost is expected to be higher for larger MPAs, when considered per unit area, small MPAs may be more expensive to establish than large MPAs, reflecting economies of scale. Furthermore, this initial component of total financial cost is likely to increase as the duration of the establishment phase is lengthened. Overall, greatest cost efficiency per unit area may be achieved for large MPAs established in a relatively short period of time (provided the establishment phase is long enough to ensure future effectiveness). Confidence in the results of this study, as well as the level of understanding of establishment costs, will be enhanced by the compilation and analysis of larger data sets which will perhaps emerge following the publication of this contribution.

Acknowledgements

The authors would like to thank the many colleagues that generously provided cost data as well as valuable insight into the process of establishing marine protected areas. The use of ArcGIS mapping software was made possible by grant from the Canadian Foundation for Innovation/BC Knowledge Development Foundation to Kai M.A. Chan. This contribution is part of the *Sea Around Us* Project, a collaboration between the Pew Environment Group and the University of British Columbia.

Appendix A. Description of MPAs

All six Philippine MPAs described by Butardo-Toribio et al. [11] were included in this study. According to White et al. [14], coastal management programs in the Philippines are focused on curbing both the destruction of habitats (i.e., coral reefs, seagrass beds, and mangrove forests) and overexploitation by fishers in order to ensure food security and maintenance of income to coastal residents. The Villahermosa Marine Sanctuary (MS) and Pilar Municipal Marine Park (MMP) are located in the Camotes Sea, near the Camotes Islands of the province of Cebu. The Bibilik, Talisay, Tambunan, and MISSTA (Militar, Sto. Niño, Sugod and Tagulo) MPAs are found in Illana Bay in the province of Zamboanga del Sur. Originally reported in Philippine pesos, establishment costs were first converted to U.S. dollars of the same year using the market exchange rate provided by the PACIFIC Exchange Rate Service,[3] and then converted to 2005 U.S. dollars according to the U.S. consumer price index[4] (CPI). All of the MPAs are characterized by a relatively low cost of establishment (min=$7528 (2005 USD), max=$20,158, mean=$13,113) and short establishment phase (min=1.5 years, max=3 years, mean=2 years). The end of this phase coincided with formal designation. These MPAs were established according to the most common method described for the Philippines: "through local community involvement at the barangay level within the context of a municipal or city government ordinance and support" [10]. This is reflected in the sources of establishment funding. With the exception of Talisay MPA, the majority of funds were contributed by sub-national, governmental institutions (Table 3). All but one MPA (i.e., MISSTA) received contributions in the form of community volunteer labor and in-kind donations from private individuals and businesses in the Philippines. Additional bilateral, governmental support was provided by the USAID/EcoGov2 project. National governmental agencies contributed to only two of the six MPAs, and in both instances was the smallest source of funding. For each of these MPAs, establishment contributions were allocated towards similar categories: infrastructure (including the construction of guardhouse and outpost buildings, the purchase of boats, and installation of marker buoys), planning (including organization and management planning activities, and legal designation costs) and research (i.e., resource assessment).

The primary objective of Chumbe Island Coral Park (CHICOP), located west of Zanzibar, Tanzania, was the conservation of intact coral reef and island ecosystems in a region subject to overexploitation [15]. Creation of this MPA was largely a private initiative overseen by Chumbe Island Coral Park Ltd., founded in 1991 to establish and manage the reserve. The establishment phase began three years prior to the creation of an institutional framework for the establishment and management of MPAs in

[3] http://fx.sauder.ubc.ca.
[4] ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt.

Tanzania, i.e. the Marine Parks and Reserves Act of 1994. As a result, the project was fraught with delays in negotiating with the government for official designation of the MPA, as well as issuance of the land lease and project permits [16]. These delays contributed to an approximate six-fold increase in the total cost of establishment relative to the initial projected cost. Due to its small size, this spending translated to the highest cost per unit area of all MPAs included in this study (Table 2). Most of the contributions were derived from bilateral sources, including a private individual, the governments of Germany and the Netherlands, and volunteer labor from German, British, and Irish agencies, with the European Commission donating less than 1% of the total (Table 3). Almost half of the cost of establishment was directed towards infrastructure, including the construction of a visitor's center and seven 'eco-bungalows,' the purchase of patrol boats, and the development of forest and marine nature trails. Efforts to minimize the ecological impact of all buildings on the island contributed to the relatively high infrastructure costs. The remaining funds and volunteer labor were dedicated to the legal costs associated with negotiating park and management contracts with the Government of Tanzania, outreach to the adjacent fishing communities and villages, development of a management plan, training of former fishermen as park rangers, research surveys of the local flora and fauna, and rat eradication. The end of the establishment phase was assumed to coincide with the start of commercial ecotourism operations which continue to generate the revenue required for the enforcement, management and administration of the park. Since its creation, CHICOP has received numerous international awards.

Saba Marine Park (MP) and Bonaire National Marine Park (NMP) encircle the small islands of Saba and Bonaire in the Netherland Antilles, encompassing coastal and coral reef habitats from the shoreline to a depth of 60 m. The establishment phase for Bonaire NMP began in 1979 with the objectives of protecting and ensuring the sustainable recreational and commercial use of Bonaire's marine resources and habitats. Initial funding was provided by national (Dutch) and local governments, as well as a national NGO [17]. This money was allocated towards infrastructure (including mooring installation, placement of a marine nature trail and dive-site markers, and renovation of existing structures to serve as the park headquarters, visitor's center and field research station), outreach (including informational brochures), and research (including surveys of the coral reef and coastal habitats as well as scuba diving activity) [18]. Failure to establish a visitor fee system and exhaustion of initial funding by 1984 resulted in the inability to effectively manage the park. However, in 1990 interest in the park was renewed, and "the Dutch government approved funding and technical assistance for the revitalization of Bonaire Marine Park" [18] with the provision that a visitor fee be introduced. By 1992 enough money was generated by these fees to begin to cover the costs of MPA management. It should be noted that Bonaire NMP was unable to provide complete financial data for this study, including the approximate amount of funding donated by each entity and the existence of other donors or volunteers.

The establishment phase of Saba MP began in 1984 following local government interest in strengthening the economy via the development of the diving industry, resulting in a proposal for the MPA. However, data regarding spending during this time period were not available for this study. Official funding for the establishment process became available in 1986, and was also conditional on the eventual implementation of a visitor fee system to ensure long-term financial sustainability. The Dutch government was the largest contributor to the establishment of the MPA, while funds were also provided by two national NGOs and the Saba government (Table 3). According to Walker [19], 71% of this money was allocated towards park personnel, as well as infrastructure (i.e., a boat, truck, radios, installation of moorings, and other miscellaneous equipment; 13%), administrative costs (10%), and outreach (i.e., brochures and guides; 6%).

The Nha Trang Bay MPA is located adjacent to coast of the Khanh Hoa Province in south-central Vietnam, and encompasses the coral reef, mangrove, and seagrass habitats surrounding ten islands. The site was selected as Vietnam's first MPA in order to protect the high level of coral reef biodiversity from the threats posed by "illegal fishing methods, poorly planned and controlled tourism development, and intensive, unregulated aquaculture development" [20]. Establishment of this MPA began with the Hon Mun Marine Protected Area Pilot Project implemented by the Global Environment Facility (GEF) starting in 1999. Over $2 million (2005 USD) was allocated to MPA establishment and implementation over a period of about five years. The majority of funding was donated by the World Bank through GEF and the International Union for the Conservation of Nature (IUCN) (Table 3). Additional support was provided by the Danish International Development Agency (DANIDA), the Government of Vietnam, and volunteer and in-kind donations from the local community (Table 3). During the initial set-up phase of the project, planning activities (i.e., the initial project proposal, development of a management plan with the participation of the local community, and critical infrastructure, including an MPA office, ranger station, etc.) accounted for nearly 20% of project spending. Additional funds were used to train MPA staff and build support of local stakeholders (11%), institute and conduct a research and monitoring program (8%), and develop alternative-income generating activities for displaced local fishers (3%) [20]. Following the initial set-up phase, the remaining funds were used for implementation of the proposed management plan. It is likely that the establishment of the Nha Trang Bay MPA was more expensive than other MPAs subsequently established in Vietnam due to the fact that it was the nation's pilot MPA, and a significant amount of money was spent on trial approaches and international expertise that may not have been necessary in other locations (B. O'Callaghan pers. comm., IUCN, 24 March 2010).

The Seaflower MPA, designated by Colombia in 2005, provides protection for the biodiverse and economically valuable coastal and marine resources of the San Andres Archipelago in the southwestern Caribbean Sea. This relatively large MPA is located within the boundaries of a larger UNESCO Biosphere Reserve established in 2000, and is zoned for multiple uses, including no-entry and no-take zones comprising 4% of the total area. Similar to the Nha Trang Bay MPA, the establishment of this MPA was also implemented by the GEF. Approximately 44% of the total cost was required for the first stage of establishment which began in 2001 and involved the development of a management plan, resource-management training and outreach to local stakeholders, research expeditions and socio-economic surveys, and project administration [21]. Following official designation, a shortage of adequate financing and technical support in combination with continued overexploitation by fisheries, unsustainable tourism, and the impacts of terrestrial run-off led to a second round of GEF-implemented funding [22,23]. The objectives of this second phase of establishment are to implement and enforce the management plan, develop a monitoring system and alternative-income generating plan, and ensuring long-term financial self-sustainability. It is anticipated to last 5 years, and cost over $8 million (2005 USD). The majority of funding for this MPA was provided by the sub-national entity, CORALINA, responsible for managing the environment and natural resources of the San Andres Archipelago (Table 3). Overall, allocation of funds to the various spending categories was similar to Nha Trang Bay MPA.

Among the largest MPAs in existence today, the Marianas Trench and Papahānamokuākea Marine National Monuments (MNM) were designated by the United States in 2006 and 2009, respectively. Protection of the Northwestern Hawaiian Islands began in 1909 with the creation of the Hawaiian Islands Reservation for the purpose of safeguarding nesting seabird colonies from overexploitation. For the purposes of this study, the establishment phase of PMNM was assumed to begin in 2001, following the designation of the Northwestern Hawaiian Island Coral Reef Ecosystem Reserve in 2000. Shortly after, efforts were initiated to add the area to the national system of marine sanctuaries and consequently increase the level of protection. After approximately five years of work by numerous national NGOs and governmental agencies, the area was proclaimed a Marine National Monument. The establishment phase was assumed to end following the acceptance of a management plan in 2008. Over 99% of funding was provided by national NGOs and governmental agencies. It is interesting to note that approximately 20% of the total cost of establishment was allocated towards a compensation program for Northwestern Hawaiian Islands commercial bottomfish and lobster fishermen who were displaced by the creation of PMNM.

The Marianas Trench Marine National Monument (MNM), located in the Commonwealth of the Northern Mariana Islands, is divided into three components: the 'islands unit' encompassing the waters and submerged lands of the three northernmost Mariana Islands (9% of the total area), the 'trench unit' including the submerged lands of the Mariana Trench (45%), and the 'vents unit' including the submerged lands of 22 seamounts and active hydrothermal submarine volcanoes (46%). This MPA was established with the objective of protecting high fish biomass and coral diversity found in the reef ecosystems, as well as "the greatest diversity of seamount and hydrothermal vent life yet discovered".[5] Commercial fishing is prohibited in the island's unit. The establishment phase began with the work of a national NGO in 2007, and is predicted to end in 2012. The cost of the first 3.5 years of the establishment phase includes funding dedicated to project proposal and advocacy, outreach to the local community, scientific research, and development of a legal framework for the designation of the monument. It is anticipated that development of a management plan as well as acquisition and construction of necessary infrastructure will occur during the remainder of the establishment phase.

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