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Filling the Data Gap – A Pressing Need for Advancing MPA Sustainable Finance

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Reaching protected area (PA) coverage goals is challenged by a lack of sufficient financial resources. This funding gap is particularly pervasive for marine protected areas (MPAs). It has been suggested that marine conservationists examine examples from terrestrial protected areas (TPAs) for potential solutions to better fund MPAs. However, the funding needs for MPAs and TPAs have not been directly compared, and there is risk of management failures if any such differences are not properly considered when designing MPA financial strategies. We perform an in-depth literature review to investigate differences in distribution of costs incurred by MPAs and TPAs across three primary categories; establishment, operational, and opportunity costs. We use our findings to conduct a snapshot quantitative comparison, which we complement with theoretical support to provide preliminary insight into differences between MPA and TPA costs, and how these may influence financial strategies most appropriate for each type of PA. Our research suggests that TPA costs, and thereby funding requirements, are greater for the time period leading up to and including the implementation phase, whereas MPAs have higher financial requirements for meeting long-term annual operational costs. This may be primarily due to the prevalence of private property rights for terrestrial regions, which are less frequently in place for ocean areas, as well as logistical requirements for enforcement and monitoring in a marine environment. To cement these suggestions in greater analytical certainty, we call for more thorough and standardized PA cost reporting at all stages, especially for MPAs and PAs in developing countries. The quantity and quality of such data presently limits research in PA sustainable finance, and will need to be remedied to advance the field in future years.

Keywords: conservation finance, protected area costs, protected area management, funding protected areas, sustainable finance, marine protected areas (MPAs), property rights

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INTRODUCTION

Implementation of protected areas (PAs) for conservation restricts human activities, such as exploitation or extraction of natural resources, within targeted ecosystems. In so doing, PAs may preserve biodiversity in key areas, allow degraded ecosystems to recover, and increase resilience to the impacts of climate change (O'Leary et al., 2018). The rising popularity of PAs in recent decades is evidenced by the multiple global initiatives that have come into force to expand PAs around the world (United Nations Environment Programme, 2011; United Nations Department of Economic and Social Affairs, 2017). These initiatives typically have separate goals for marine protected areas (MPAs) and land based PAs [which we refer to here as terrestrial protected areas (TPAs)]. Aichi target 11, formed in 2010 under the Convention for Biological Diversity (CBD), aims to have 10% of the ocean (within Exclusive Economic Zones) and 17% of land area protected by the year 2020. Following the CBD targets, the United Nations established a target of conserving 10% of the entire ocean by 2020 under Goal 14 Target 5 of the UN Sustainable Development Goals. IUCN has recommended an additional long term goal of protecting 30% of the ocean by 2030. In comparison, goals for TPA coverage have a particularly long history spanning multiple decades, including the IVth World Parks Congress under IUCN in 1992 that aimed to have 10% of each biome under protection by 2000 (IUCN, 1993).

In light of these PA expansion goals, there is much concern over how to generate adequate financial resources to achieve them. Costs that PAs incur are typically broken down into three categories (James et al., 2001; McCarthy et al., 2012; Brander et al., 2015), which are described as follows:

Establishment Costs – All costs in the time period from project conception up to active implementation. This may include purchase of land or other acquisition costs, administration costs, legal fees, transaction costs, research and surveys, and initial capital costs for enforcement equipment, tourism, or other capital infrastructure.

Operational Costs – year to year costs for management, monitoring, and enforcement. This may also include maintenance, scientific research for tracking PA performance, and employee salaries. Routine activities related to education and public or stakeholder outreach also fall under this category.

Opportunity Costs – the society wide benefits that are foregone by the restriction of economic activities resulting from implementation of the PA. Opportunity costs are frequently borne by external stakeholders, rather than the PA managing agency or institution directly. Opportunity costs may sometimes be a part of the budget for the PA in the event that management pays compensation to groups or individuals that lose income as a result of PA implementation.

A lack of adequate funding to meet PA costs both impedes the ability to expand PA networks, and may render existing PAs ineffective in reaching their conservation goals (Bruner et al., 2004; Edgar et al., 2014; Gill et al., 2017), regressing to what is referred to as "paper park" status (Thur, 2010). Furthermore, there is a general global funding gap for conservation at large. In 2014, Credit Suisse in partnership with McKinsey & Company, WWF, and Yale University released a comprehensive overview of the state of conservation finance. The report estimated that about $300-$400 Billion would be required per year to preserve healthy ecosystems around the globe, but only $52 Billion per year is actually being delivered (Huwyler et al., 2014).

While the funding gap applies to both marine and terrestrial conservation, there is a stark difference in the advancement of and available resources for TPAs versus MPAs. TPAs are much closer to reaching their expansion goal of 17% having achieved 14.8% coverage by the end of 2016 (Hussain et al., 2011; UNEP-WCMC and IUCN, 2016; United Nations Department of Economic and Social Affairs, 2017), whereas MPA coverage had only reached 5.1% by that time (UNEP-WCMC and IUCN, 2016). While MPA coverage has grown in recent years [estimated by the World Database on Protected Areas at 7.4% in October 2018 (Marine Protected Areas Coverage in 2018, 2018)], coverage still falls far short of the 10% by 2020 target, and fully or strongly protected MPAs comprise a small percentage of the total (Sala et al., 2018). In addition, marine ecosystems are particularly underfunded among PAs as a whole (Emerton et al., 2006; Bruner et al., 2008). Review of the currently available literature reveals that there are more studies of TPA costs than those of MPA costs, which only a handful of available sources directly address (Balmford et al., 2004; Gravestock et al., 2008; McCrea-Strub et al., 2011; Brander et al., 2015). The historic advancement of terrestrial versus marine conservation in implementation, research, and resource allocation fits with one researcher's description of marine ecosystems as the "Cinderella" of conservation (McIntyre, 1992 as quoted in Jones, 2014).

Financial mechanisms used to fund TPAs are currently more diverse and sophisticated than those used for MPAs. Thus, it may be instructive to consider successes in terrestrial conservation finance for MPA funding guidance (De Santo, 2012). Examples of traditionally TPA-oriented funding mechanisms that are now being applied to MPAs include debt-for-nature swaps (Gockel and Gray, 2011; Baird et al., 2017; Weary, 2017) and "blue carbon," or carbon offsets for coastal or marine specific sequestration (Murray et al., 2011; Pendleton et al., 2012; Runting et al., 2016; Baird et al., 2017). However, these mechanisms have only been employed in a handful of marine conservation projects around the world. In working toward achievement of the 10% by 2020 goal, MPA managers must continue to adapt TPA funding mechanisms and strategies to a marine context, and the growing emphasis on MPAs will present numerous opportunities for TPA finance experts to transfer their skillset to MPAs. However, for this collaboration and skills transfer to succeed, the fundamental differences between MPA and TPA finance need to be mutually understood.

This paper focuses on potential differences in costs between MPAs and TPAs, and how these relate to developing effective financial strategies. The aforementioned cost categories (establishment, operational, and opportunity) are differentiated based on whether costs are incurred upfront or whether they are ongoing year-to-year expenditures, which can make them more appropriate for some financial mechanisms over others. For example, revolving funds are used to provide immediate one time payments to recipients whereas trusts can deliver consistent payouts over a longer period of time (Clark, 2007). By definition, sustainable finance for PAs requires adherence not to just quantity of funds required, but also that funding is delivered in a timely manner in accordance with needs (Emerton et al., 2006). Thus determining any difference in the required timing of funds for MPAs versus TPAs is critical to adopting or designing effective and sustainable financial strategies. In this paper, we review the existing literature to investigate the potential for statistically analyzing the differences in the funding requirements of MPAs versus TPAs. While we ultimately find that data are very limited, we provide some quantitative and qualitative insights, and provide recommendations as to data needs that will allow fuller elucidation of sustainable finance issues.

METHODS

Literature Review

We conducted a comprehensive literature review to examine costs incurred by the groups or agencies establishing and operating PAs. Per our focus on costs, we sought articles from all geopolitical scopes that provided specific values in currency terms, either estimated or actual observations, for any of the three cost categories (**Table 1**). We developed a collection of available literature via databases "Web of Science" and "Google Scholar" using combinations of keywords and phrases including; Marine Protected Areas, Protected Areas, Nature Reserves, Marine Reserves, Costs, Management, Operations, Expansion, and Establishment. We then expanded our collection by reviewing internal citations from this initial set of articles. We also considered articles uncovered by expert input, prior research, or conference attendance. Both peer reviewed and white paper or government reports were considered, as well as studies addressing multiple spatial scales, from site-specific assessments to comprehensive global estimates. The literature was collected in multiple stages; initially from September to November 2017, and then from January to February 2018.

Quantitative Comparison

Our intent is not to compare total funding requirements between MPAs and TPAs. Rather, we compare how total funding needs are distributed among the three categories of costs that PAs can incur during different stages of development. We framed this via a series of ratios that track proportional expenditures across cost categories:

Ratio 1: Establishment Costs as a % of Total Costs.
Ratio 2: Establishment to Operational Costs (EST : OP).
Ratio 3: Establishment to (Operational and Opportunity Costs) (EST : OP + OC).
Ratio 4: (Establishment and Opportunity Costs) to Operational Costs (EST + OC : OP).

Due to the differences between studies (e.g., scope, location, and time of study) that would influence costs, we did not combine different studies in our calculation of ratios. Rather, we calculated ratios from numbers provided within the same study to avoid confounding cost ratio results with study-related differences. Therefore, in our literature review, we paid special attention to studies that contained values for multiple cost categories as a prerequisite for inclusion in the quantitative comparison portion of the review.

Each study used a different time period for their respective analysis, with some incorporating discount rates when estimating future costs. For accurate comparison, we standardized to a common time period and discount rate based on the approach used in the Brander et al. (2015) report on future costs of global MPA expansion (Brander et al., 2015). Brander calculates establishment costs over a 5-year implementation period, immediately followed by 30 years of operations. Like Brander, we return present values (PV) for the 35-year period with a 3% discount rate. All dollar values are converted to 2017 USD via the Consumer Price Index (CPI) from the Bureau of Labor Statistics. Consequently, the methodology assumes establishment costs stretched over a 5-year period from 2018 to 2022, followed by 30 years of operational costs. Opportunity costs are factored in for the full 35-year time horizon.

RESULTS

Literature Review

Our literature review yielded twenty-four articles on PA costs for different spatial and political scales published from 1999 to 2018. We cataloged and present here (**Tables 2A,B**, **3**) each piece of literature based on scope, environment considered (marine or terrestrial), the costs reported, type of data, and eligibility for inclusion in our quantitative comparison. Papers and articles include projections for real cases, estimations for hypothetical scenarios, and observations from ongoing efforts Some studies are site- or region-specific, in which case their geographic focus is also referenced (Green et al., 2012; Rojas-Nazar et al., 2015; Pascal et al., 2018). Other studies have used a collection of case examples or data sets to construct cost models to both identify variables that influence costs, as well as to project costs of

TABLE 1 | Review of data type behind reported costs and geopolitical scope for surveyed literature in review.

Data types			
Reported observation Actual costs incurred by a single or set of protected areas that have been recorded and reported.	Surveyed estimation Costs projected for hypothetical expansion or implementation of new PAs via survey responses from PA managers or other experts.	Literature estimation Costs projected for hypothetical expansion or implementation of new PA via review of available literature.	Calculated estimation Costs projected for hypothetical expansion or implementation of new PAs calculated using existing model or other objective method.
Spatial/political scopes			
Site specific Cost numbers are attributed to a specific PA or local network of PAs.	National Aggregated costs for all PAs of a given type in a specific country.	Regional Aggregated costs for all PAs of a given type across a continent or region (e.g., Mediterranean Sea).	Global Aggregated costs for all PAs of a given type for a global target or hypothetical expansion scenario.

TABLE 2A | Literature review summary results for exclusively marine or joint marine-terrestrial studies.

Author	Year	Title	Peer reviewed?	Scale	Environment	Costs			Data type	Eligible for analysis?
						Establishment	Operational	Opportunity		
Klein et al., 2010	2010	Prioritizing land and sea conservation investments to protect coral reefs	Y	National (Indonesia)	Both		X	X	Estimations (calculated)	Yes
Gantioler et al., 2010	2010	Costs and socio-economic benefits associated with the Natura (2000) network	N	Regional (Europe)	Both	X	X		Estimations (surveyed)	Yes
Pascal et al., 2018	2018	Evidence of economic benefits for public investment in MPAs	Y	Site specific (Vanuatu and Saint Martin)	Marine	X	X		Observations	Yes
Binet et al., 2016	2015	Sustainable financing of Marine Protected Areas in the Mediterranean: a financial analysis	N	Regional (Mediterranean)	Marine	X	X		Observations and estimations (surveyed)	Yes
Brander et al., 2015	2015	The benefits to people of expanding Marine Protected Areas	N	Global	Marine	X	X	X	Estimations (calculated)	Yes
Rojas-Nazar et al., 2015	2015	Marine reserve establishment and on going management costs: a case study from New Zealand	Y	Site Specific (network of MPAs in New Zealand)	Marine	X	X	X	Estimations (calculated and surveyed) and observations	Yes

(Continued)

TABLE 2A | Continued

Author	Year	Title	Peer reviewed?	Scale	Environment	Costs			Data type	Eligible for analysis?
						Establishment	Operational	Opportunity		
United Nations Development Programme [UNDP], 2012	2012	Catalysing ocean finance volume I: transforming markets to restore and protect the global ocean	N	Global	Marine	X	X		Estimations (calculated)	Yes
Ban et al., 2011	2011	Promise and problems for estimating management costs of marine protected areas	Y	Site Specific (The Coral Sea, Australia)	Marine		X		Estimations (calculated and surveyed)	No
McCrea-Strub et al., 2011	2011	Understanding the cost of establishing marine protected areas	Y	Global	Marine	X			Observations	No
Gravestock et al., 2008	2008	The income requirements of marine protected areas	Y	Global	Marine		X		Observations	No
Balmford et al., 2004	2004	The worldwide costs of marine	Y	Global	Marine		X		Observations	No

Column for "Data Type" indicates whether costs were direct observation or estimations, and if estimations were developed by answers to surveys, calculated by the authors, or possible ranges via literature review. [Citations not included in text (Ban et al., 2011)].

TABLE 2B | Literature review summary results for exclusively terrestrial studies.

Author	Year	Title	Peer reviewed?	Scale	Environment	Establishment	Operational	Opportunity	Data type	Eligible for analysis?
Venter et al., 2014	2014	Targeting global Protected Area expansion for imperiled biodiversity	Y	Global	Terrestrial			X	Estimations (calculated)	No
Green et al., 2012	2012	Estimating management costs of protected areas: a novel approach from the Eastern Arc Mountains, Tanzania	Y	National (Tanzania)	Terrestrial		X		Observations and estimations (surveyed and calculated)	No
McCarthy et al., 2012	2012	Financial costs of meeting global biodiversity conservation targets: current spending and unmet needs	Y	Global	Terrestrial	X	X		Estimations (calculated)	Yes
Hussain et al., 2011	2011	The economics of ecosystems and biodiversity	N	Global	Terrestrial	X	X	X	Estimations (literature review)	No
Pearce, 2007	2007	Do we really care about biodiversity?	Y	Global	Terrestrial		X	X	Estimations (literature review)	No
Bruner et al., 2004	2004	Financial costs and shortfalls of managing and expanding Protected-Area systems in developing countries	Y	Global	Terrestrial	X	X		Estimations (literature review)	No
Moore et al., 2004.	2004	Integrating costs into conservation planning across Africa	Y	Regional (Africa)	Terrestrial		X		Estimations (calculated, using Balmford, 2003)	No
Balmford et al., 2003	2003	Global variation in terrestrial conservation costs, conservation benefits, and unmet conservation needs	Y	Global	Terrestrial		X		Observations	No

(Continued)

TABLE 2B | Continued

Author	Year	Title	Peer reviewed?	Scale	Environment	Establishment	Operational	Opportunity	Data type	Eligible for analysis?
Frazee et al., 2003	2003	Estimating the costs of conserving a biodiversity hotspot: case-study of the Cape Floristic Region, South Africa	Y	Site specific (South Africa)	Terrestrial	X	X		Estimations (calculated)	Yes
Shaffer et al., 2002	2002	Noah's options: initial cost estimates of a national system of habitat conservation areas in the United States	Y	National (United States)	Terrestrial	X	X		Estimations (calculated)	Yes
James et al., 2001	2001	Can we afford to conserve biodiversity	Y	Global	Terrestrial	X	X		Estimations (calculated)	Yes
TNC (Curtis et al., 2001)	2001	Planificacion financiera a largo plazo para parques y areas protegidas	N	Regional (Latin America)	Terrestrial		X		Estimations (calculated)	No
James et al., 1999	1999	A global review of Protected Area budgets and staff	N	Global	Terrestrial		X		Observations	No

Column for "Data Type" indicates whether costs were direct observation or estimations, and if estimations were developed by answers to surveys, calculated by the authors, or possible ranges via literature review (Citations not included in text James et al., 1999; Curtis et al., 2001; Shaffer et al., 2002; Frazee et al., 2003).

TABLE 3 | Number of articles by data type and geo-political scope.

Data types			
Reported observation	Surveyed estimation	Literature estimation	Calculated estimation
9	5	2	13
Spatial/political scopes			
Site specific	National	Regional	Global
4	3	4	13

Some studies included multiple sources to generate their cost figures, e.g., both surveyed as well as calculated estimations (see ***Table 2****).*

expansion on a global scale (Balmford et al., 2003, 2004; Moore et al., 2004; Gravestock et al., 2008; McCrea-Strub et al., 2011). These papers are particularly influential in the field as many other studies adopted their models for cost projections. Another subset of influential work includes papers that estimate costs for reaching specific global conservation goals, such as Aichi Target 11 and the UN's SDG 14.5 (James et al., 2001; McCarthy et al., 2012; United Nations Development Programme [UNDP], 2012; Brander et al., 2015).

Operational costs were the most commonly reported cost within the literature reviewed with 22 of 24 papers returning values. Establishment costs were less frequently reported, with 13 studies having figures. Only five studies returned values for opportunity costs, though this is partly attributed to our focus on costs being incurred by the PA, rather than costs borne by society at large. As mentioned in the introduction, opportunity costs would only translate to costs incurred by a PA managing agency if compensation is paid to those losing economic opportunities because of PA establishment. While there are examples of compensation packages for fishers as part of PA budgets like in the Great Barrier Reef (Macintosh et al., 2010), current literature suggests that such direct monetary compensation packages remain challenging especially for Marine PAs due to a lack of stakeholder use and activity data and are likely rare overall (McCay and Jones, 2011). Furthermore, it is possible that some of the studies we analyzed already accounted for such compensatory payments (and therefore a portion of opportunity costs) within their calculations for establishment and operational costs, perhaps contributing to the data limitations for opportunity costs. Hence, when discussing results going forward, operational and establishment costs are the primary focus and opportunity costs are a secondary consideration. However, we still accounted for and report ratios for opportunity costs when possible.

Quantitative Perspective

Fourteen works provided values across the required cost categories. Not all of these studies were eligible, however. Studies were deemed ineligible for the analysis if (1) costs were incompletely or inadequately reported or estimated (Venter et al., 2014), or (2) if they did not provide adequate distinction for how costs were distributed by category (Pearce, 2007; Hussain et al., 2011; Binet et al., 2016), marine vs. terrestrial environment, or a combination of both (Gantioler et al., 2010; Binet et al., 2016). Additionally, we removed Bruner et al. (2004) from eligibility as the only establishment cost estimate it provided was directly taken from James et al. (2001), which we already accounted for in the literature review (Bruner et al., 2004).

After filtering out these ineligible works, we were left with 10 studies to compare ratios against, only nine of which accounted for establishment costs. The combination of limited samples, combined with the fact that many samples were replicates of common estimation models (Balmford et al., 2003, 2004; McCrea-Strub et al., 2011), prevented us from conducting a detailed statistical analysis to test for a significant difference of cost ratios between MPAs and TPAs. Still, we provide an initial estimate of potential ranges and differences from the available data (**Figure 1** and **Table 4**). Most studies reported costs for a range of scenarios (e.g., cost estimates for total area protected versus cost estimation based on protection priorities (Brander et al., 2015), cost estimates based on MPA size (United Nations Development Programme [UNDP], 2012), cost estimates by wealth of country (McCarthy et al., 2012). The figures reported in **Figure 1** and **Table 4** correspond with the minimum and maximum ratios within each study across all scenarios presented.

Terrestrial protected areas generally hold higher values than MPAs for Ratio 1 (establishment costs as % of total) and Ratio 2 (establishment costs to operating costs). In all but one case, the exception being the minimum bound for Natura (2000), establishment costs for TPAs make up over 70% of total costs, and have a Ratio 2 of at least 2.68 implying that the majority of costs would be incurred prior to implementation. In contrast, establishment costs for MPAs make up a maximum of 39.40%, and all Ratio 2 values are well-below 1.00 such that the majority of costs are estimated to occur over the operational time period. In fact, there is no overlap in Ratio 2 values between MPAs and TPAs with the one exception again being the minimum bound of the Natura (2000) study, which slightly overlaps with the maximum values for MPAs under Brander and UNDP. Opportunity costs were only included in Klein et al. (2010), Brander, and Rojas-Nazar studies, so our ability to compare TPAs versus MPAs on the basis of Ratios 3 and 4 is quite limited. However, Ratio 4 is generally higher for the TPA than MPA scenarios.

DISCUSSION

Taking Stock of Current Literature

While our review is unique in its comparative focus on MPAs versus TPAs, it is not the first literature review to be conducted on costs incurred by PAs. Bruner et al. (2004) and Pearce (2007) are two examples included in our literature review that discuss a collection of literature assessing different types and methods

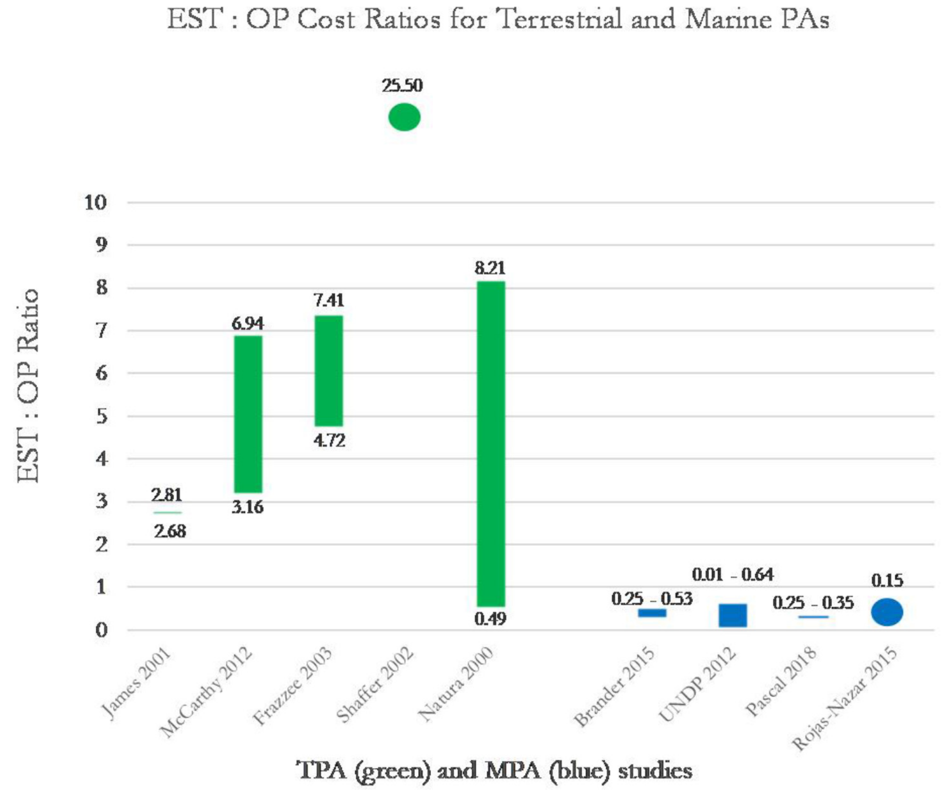

FIGURE 1 | Graphic demonstrating the range of Ratio 2 values (Establishment to Operational costs) calculated for five TPA and four MPA studies from **Table 4**. Bars indicate the boundaries of minimum and maximum ratio values for individual studies. Circles denote ratios for studies that only returned one value. The range of values are written next to their corresponding bars and circles.

TABLE 4 | Cost ratios per each eligible study.

	Ratio 1	Ratio 2	Ratio 3	Ratio 4
	EST as % of total	EST – OP	EST : OP + OC	EST + OC : OP
Terrestrial				
James et al., 2001	72.80 – 73.77%	2.68 – 2.81	2.68 – 2.81	2.68 – 2.81
McCarthy et al., 2012	75.97 – 87.41%	3.16 – 6.94	3.16 – 6.94	3.16 – 6.94
Klein et al., 2010*	N/A	N/A	N/A	1.30 – 13.99
Frazee et al., 2003	82.53 – 88.11%	4.72 – 7.41	4.72 – 7.41	4.72 – 7.41
Shaffer et al., 2002	96.23%	25.5	25.5	25.5
Gantioler et al., 2010**	32.91 – 89.14%	0.49 – 8.21	0.49 – 8.21	0.49 – 8.21
Marine				
Brander et al., 2015	2.63 – 12.52%	0.25 – 0.53	0.03 – 0.14	1.25 – 8.55
United Nations Development Programme [UNDP], 2012	1.16 – 39.40%	0.01 – 0.65	0.01 – 0.65	0.01 – 0.65
Pascal et al., 2018	8.71 – 20.10%	0.10 – 0.25	0.10 – 0.25	0.10 – 0.25
Rojas-Nazar et al., 2015	11.88%	0.15	0.13	0.23
Klein et al., 2010	N/A	N/A	N/A	0.002 – 3.78

**Klein et al., 2010* *does not include establishment costs, so Ratio 4 is exclusively Opportunity Costs to Establishment Costs. **Scenarios included from Natura (2000) are for countries where MPAs were ruled out as the study did not adequately differentiate cost distribution by environment for countries where both MPAs and TPAs were present.*

calculating PA costs (Bruner et al., 2004; Pearce, 2007). However, both of these studies strictly look at terrestrial sources of funding. In addition, they both have similar faults and expose common gaps in information on this topic.

As discussed in the introduction, MPAs and financial research surrounding MPAs are generally not as in depth and widespread as their TPA counterparts. The focus of Bruner et al. (2004) and Pearce (2007) on terrestrial ecosystems is indicative of this trend.

Further, only nine studies focused exclusively on marine areas, with two additional studies looking at both types simultaneously. The materials included within Bruner and Pearce also indicate that establishment costs are much less frequently reported than operational costs for PAs in general. For example, while Bruner included a total of 15 studies, only James et al. (2001) included a direct estimate of establishment costs.

We came across several other informative sources during the research process that, while not included in our final tabulation, referenced the state of available information on PA costs. Several cited a lack of adequate data collection on conservation costs in general, including PAs (Naidoo et al., 2006; Ban and Klein, 2009; Kark et al., 2009; Cook et al., 2017). More specifically, data for marine planning and acquisition costs (as part of establishment costs) for PAs in developing countries have been cited as especially difficult to acquire (Balmford et al., 2003; Naidoo et al., 2006; Ban and Klein, 2009). This pattern is represented to a degree in our literature review with fewer works containing establishment cost estimates than operational cost estimates.

The dispersed nature of information within our review, as well as from qualitative references in other works, highlights specific gaps in the literature and directions for future focus in closing these knowledge gaps. Improving cost data in marine areas, and establishment cost data in both marine and terrestrial environments, needs to be a primary focus in order to improve assessment of financial sustainability for PAs. Researchers have also called for standardization of reported information in order to make data from different sources easier to compare (Binet et al., 2016; Cook et al., 2017). Such recommendations have included reporting of common line items or cost categories, as well as systematic methods of calculation and accounting. We experienced challenges ourselves from the lack of standardized reporting methodologies while trying to compare costs across different studies. Some experts and researchers have referenced global health programs as a bar for cost reporting that conservation efforts can try to emulate (Cook et al., 2017).

Quantitative Snapshot

Our comparison of the time distribution of costs obtained by tracking across multiple cost categories provides an initial understanding of differences between MPAs and TPAs that can be followed up by evaluation at an individual MPA and TPA level. We observe a common pattern where establishment costs make up a far greater share of costs for TPAs than MPAs. In the context of meeting financial needs, this may indicate that TPAs require a greater share of total funding requirements in costs leading up to implementation, whereas costs for MPAs are incurred on more of a long term year-to-year basis for management, monitoring, and enforcement.

While we are limited in observations pertaining to opportunity costs, Klein et al. (2010) estimate higher opportunity costs as a proportion of management costs for terrestrial regions than marine areas. In that study, opportunity costs were influenced by agricultural rents and income from fishing for TPAs and MPAs respectively, indicating that compensatory payments could perhaps be higher for infringement on land development than extraction of marine natural resources. However, the nature of and amount to which these opportunity costs might result in compensatory payments is likely variable across countries. For that reason, it is important to have a globally representative spread of PA cost data to get a complete picture of PA costs, rather than, for example, data from strictly developed countries that may have better reporting capacity.

Theoretical Interpretation

Below we provide potential theoretical support for the observed findings on differences in cost ratios in TPAs versus MPAs. Similar to our quantitative comparison, the intent is to provide an initial perspective on TPA versus MPA costs and their implications for financing strategies.

Property Rights

Perhaps the greatest fundamental difference between MPAs and TPAs is the prevalence of private property rights in policies and spatial management of land versus sea. Purchasing private property rights as an establishment cost should therefore theoretically play a greater role in the costs of TPAs than MPAs. Private property rights are generally more prevalent in land-based scenarios due in part to the relative ease of identifying and establishing boundaries (Jones, 2014). Parties that can hold private property rights include individuals (for residence and commercial use), corporations, and in some cases communities that restrict use of land to community members. Some of the most frequent commercial uses for private land include agriculture or timber, which according to Maxwell et al. (2016) are also the two greatest threats to terrestrial biodiversity at large (Maxwell et al., 2016). The widespread threat of agriculture to terrestrial conservation, and the frequency with which TPAs are likely to require purchases of private land, is also demonstrated by many studies in our review that incorporate agricultural land values into considerations for estimating costs. Such examples include the McCarthy et al. (2012) study that exclusively relied on agricultural land values to estimate global costs of TPA expansion. In addition, Klein et al. (2010) and Venter et al. (2014) studies incorporate opportunity costs as a function of agricultural rents, and James et al. (2001) and Shaffer et al. (2002) used land market values to calculate purchase prices under establishment costs. Despite slight differences in methodologies, we find that TPA studies commonly calculate expansion costs as directly related to the value of private property and use rights, and thereby view expansions as directly imposing onto private land in the majority of cases.

For the ocean, quasi-property rights can be introduced spatially via mechanisms such as Territorial Use Rights for Fishing (TURF) that give permitted vessels exclusive access over certain fishing grounds. In addition to zonal rights, access rights can be allocated to specific uses across a marine area, including to specific resources and industries. Not only are private property rights very rare in ocean regions (Jones, 2014), but the ocean and its resources have also been generally viewed through the lens of open access, such that development of private property rights is frequently considered a form of conservation itself. In some cases, areas with private property rights for marine resources have been considered de facto MPAs, also referred to by state agencies as DFMPAs (National Marine Protected Areas Center, 2008; Jones, 2014). One example is the leasing of marine areas for offshore wind energy, which has been discussed as having positive conservation benefits for the restrictions placed on fishing in such areas (Coates et al., 2016; Hammar et al., 2016).

Therefore, the use of private property rights as a conservation measure suggests that future MPA expansions may be less likely to encroach on regions where marine private property rights presently exist, whereas TPAs are likely to target areas with private property rights to restrict industries like timber, mining, and agriculture that are substantial threats to terrestrial conservation. Property rights (or the lack thereof) pose an interesting paradox for marine conservation in that a lack of property rights has frequently been associated with over exploitation and ecosystem degradation, yet may also provide an opportunity to establish MPAs at a lower cost than if property rights were more widespread.

Logistics and Operational Costs for Management

When analyzing costs of PAs, it is important to consider the logistical differences between required management, monitoring, and enforcement activities in marine versus terrestrial environments. While such differences have never been directly compared in a quantitative manner, studies have outlined general differences between marine and terrestrial conservation. In one example of a feasibility assessment for MPAs in Sweden, the authors cited Swedish administrative officials as claiming that MPAs are substantially more expensive to manage than TPAs, including monitoring and enforcement (Grip and Blomqvist, 2018). This was primarily attributed to a need for ships and advanced technology required for monitoring and enforcement in a marine environment. While ships are expensive to purchase, the operating costs of vessels is also particularly high. For reference, a recent study on MPA monitoring assumed $30,000/day for ship time (Kachelriess et al., 2014). While this estimate is specific to larger offshore vessels, even the smallest vessels for coastal or nearshore monitoring can cost 100s of dollars per day.

It is also important to consider potential differences in PA size between marine and TPAs and their influence on logistics and thereby operational costs, especially because comparative research finds that MPAs are larger on average than TPAs (Lindholm and Barr, 2001) and that the largest PAs in the world are typically MPAs[1]. Larger PAs generally require higher total operational costs. However, research indicates that larger PAs have lower operational costs per unit area than smaller PAs (Balmford et al., 2003, 2004). Thus, in the case of our calculations for area based changes in the United Nations Development Programme [UNDP] (2012) report, larger MPAs return a higher Ratio 1 value (EST : OP) than smaller MPAs despite having higher operational costs overall (see **Supplementary Material**), presumably as the decrease in marginal establishment costs per unit area is not as substantial.

There has been much recent focus on the prospects for technological advances to lower costs (Grip and Blomqvist, 2018). Remote monitoring is an increasingly popular method for marine and terrestrial ecosystem surveillance that can reduce the need for active vessels and vehicles, with subsequent promise for cost savings and improved execution for enforcement and monitoring (Pala, 2015; Proud et al., 2016; Richards et al., 2017). For enforcement purposes, improvements in remote monitoring may benefit MPAs more than TPAs considering that land based poachers and other violators can hide under forest canopy and other terrestrial features. For monitoring ecological performance, remote sensing remains limited to surface layers of the ocean, and expensive (and sometimes environmentally harmful) *in situ* monitoring tasks such as SCUBA diving and benthic trawls are often needed (Pomeroy et al., 2004). However, further improvements in remote monitoring and advancements in other cheaper and less invasive *in situ* methods such as environmental DNA, drones, satellite images, etc. may lead to significant cuts in operational costs required for MPAs in the future (Bohmann et al., 2014; Pikitch, 2018). Future research should evaluate how the addition of new technologies may benefit MPAs and TPAs differently depending on the specific technology and PA context.

CONCLUSION

The results of our literature review revealed a lack of available data to statistically analyze differences among three categories of costs incurred by PAs. Still, our findings provide an initial perspective on how MPAs and TPAs may incur costs differently. We observe a distinct pattern in the presently available information where TPAs incur a greater proportion of costs prior to implementation, while MPAs typically incur the majority of costs over the long term. Per our observations, TPAs would ideally focus on financial strategies that can deliver the majority of total required funding prior to implementation. Meanwhile MPAs may be better candidates for strategies that can guarantee consistent and controlled funding over multiple decades. While such a pattern between one-off implementation costs and ongoing costs seems elementary in theory, perhaps it has not been given proper recognition in practice as evidenced by a lack of financial resources made available to long term MPA operations and resulting paper park status (Reid-Grant and Bhat, 2009; Thur, 2010; Gill et al., 2017). And if MPA managers have yet to give this due consideration, then this lesson is all the more relevant for terrestrial conservation finance professionals looking to focus on the many growing opportunities in marine conservation. One recent example of successfully adapting a traditional TPA funding metric to an MPA is the debt-for-nature swap in the Seychelles orchestrated by The Nature Conservancy, which includes a regimented funding plan for at least 20 years of marine conservation efforts in the country (Debt Relief for dolphins: A new plan to protect the water around the Seychelles, 2017).

Our study also leads to an even more important conclusion about research surrounding PA costs and finance. This review documents that presently available PA cost data and statistics

[1] www.protectedplanet.net

are insufficient to answer basic questions about PA costs and funding needs on a technical level. The inability to rely on rigorously collected data to conduct specific analyses will likely limit advancements in PA sustainable finance until the data gap is remedied. Furthermore, in addition to the need to expand the amount of information available, it is necessary to transition to a network of higher quality data. Only eight of the 22 studies in our literature review included any actual observations, whereas the majority of cost assessments were estimations determined either by a method of calculation or response to a survey, including all but one of the studies we were able to adapt to our quantitative comparison. To refine our understanding on PA costs and management, we need to transition from data rooted in estimations projecting hypothetical scenarios toward actual PA observations. More investment is therefore needed in both MPA and TPA conservation cost reporting, ideally in a standardized metric as recommended by other researchers in the field (Cook et al., 2017).

AUTHOR CONTRIBUTIONS

JB compiled and synthesized the background research for this work, including the literature review. He also structured and performed the comparative analysis, and organized and wrote the initial drafts of the manuscript. AD provided guidance on the development of the paper and its structure, reviewed the quantitative findings and suggested modifications, edited versions of the manuscript, and assisted in conceptualizing the implications of the research. EP contributed to the conceptualization, writing, broader context, and provided intellectual insight to the manuscript. She also helped obtain the funding with which this work was supported.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2019.00045/full#supplementary-material

TABLE S1 | Costs and calculated ratios for individual conservation scenarios within each study assessed in the quantitative comparison.

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