Sea Change: Costs and Benefits of Marine Protected Areas

Supplemental Materials

Detailed descriptions of the methodology for the Sea Change: Cost and Benefits of Marine Protected Areas analysis.[1]

Focal Countries

The analysis included geographies reflecting the likely costs and benefits of countries from both temperate and tropical regions, low to high income, and a subset with high dependencies to fisheries and/or tourism. Enabling conditions included debt to GDP ratios exceeding 75%, political interest in 30% ocean protection by 2030, and/or the potential of mobilizing financing for conservation. Not all countries met all enabling conditions, and inclusion on the list does not mean sovereign debt refinancing is possible, as further market-dependent analyses must be done at the time of restructuring the debt. Countries included in this analysis skewed heavily to Small Island Developing States (SIDS) because of The Nature's Conservancy's Blue Bonds for Ocean Conservation Strategy objective to ensure ocean biodiversity representativeness, durable finance for conservation, and the potential applicability of sustainable debt mechanisms.

Focal Countries Included in the Analysis

Angola
Argentina
Antigua and Barbuda
Benin
Bahamas
Belize
Brazil
Barbados
Chile
Ivory Coast
Cameroon
Democratic Republic of the Congo
Colombia
Comoros
Cape Verde
Costa Rica
Dominica
Ecuador
Egypt
Fiji
Micronesia
Gabon
Ghana
Guinea
Equatorial Guinea
Grenada
Guyana
Honduras
Indonesia
India
Jamaica
Kenya
Kiribati
Saint Kitts and Nevis
Liberia
Saint Lucia
Sri Lanka
Western Sahara
Madagascar
Mexico
Mozambique
Republic of Mauritius
Namibia
Nigeria
Panama
Peru
Philippines
Palau
Papua New Guinea
Senegal
Solomon Islands
Sierra Leone
El Salvador
Suriname
Seychelles
Togo
Thailand
East Timor
Tonga
Tuvalu
Tanzania
Vietnam
Vanuatu
South Africa

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Marine Protection Scenarios

To provide a range of likely costs for countries to protect 30% of their Exclusive Economic Zone (EEZ)[2], we first modeled hypothetical Marine Protected Areas (MPA) systems for each country in our sample, based on biodiversity priorities (Sala et al. 2021). We then applied three scenarios of varying levels of marine protection: "High Protection," "Mixed Protection," and "Mixed-High Protection;" and calculated the primary costs: establishment, management, and opportunity costs, associated with each of the scenarios.

All scenarios begin from the current extent of MPAs (World Database on Protected Areas (WDPA) 2021), and then expand the system in each focus country to achieve 30% coverage of the country's EEZ. We divided the EEZ into 1 km^2 cells and identified all cells already protected. Expanding from that baseline, we used the biodiversity-priority raster from Sala et al. (2021), as a ranking system. This system produces a raster in which each cell value indicates the level of biodiversity importance, using equal-area cells of approximately 3,000 km^2, therefore we downscaled the original raster to the 1 km^2 resolution, and clipped it to the borders of each EEZ[3]. We then added 1 km^2 cells to the existing MPA system to rank them based on their cell values, which indicate the biodiversity importance. When the number of the lowest-valued 1 km^2 cells exceeded the difference between the 30% protection target and the area so far achieved using all 1 km^2 cells of a higher ranked value of biodiversity, we chose to preserve contiguity, since such a practicality was likely to reflect political and operational realities in place, we then added the lowest-value cells contiguously to the cells already selected, in an east-west direction, until the 30% target was reached.

To reflect the structure of the costing algorithm and create the scenarios, selected MPA 1 km^2 cells were divided into two groups for the purpose of scenario creation: those within 12-nm of the coastline, and those beyond 12-nm limit of the coastline. We also defined two levels of protection, in a simplified structure based on current IUCN categories of protection.[4]

- **High Protection** 1 km^2 cells were modeled to allow recreational activity but not commercial fishing

- **Medium Protection** 1 km^2 cells were modeled to allow recreational activity and commercial fishing carried out in a sustainable way.

To create the different scenarios, we divided the selected MPA 1 km^2 cells across the protection levels described above, with a range of approaches designed to explore the impacts on national fishers, coastal livelihoods, and conservation priorities (Table 1).

For the "Reference" scenario (MPAs already in existence), we defined High Protection as all current MPAs classified as "Fully Highly Protected" in Sala et al. (2021), and Medium Protection as all other

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[2] Exclusive Economic Zone (EEZ): by the 1982 United Nations Convention on the Law of the Sea (UNCLOS), is an area of the sea in which a sovereign state has special rights regarding the exploration and use of marine resources, including energy production from water and wind.

[3] Spatial EEZ outlines were taken from the World EEZ v11 product at marineregions.org

[4] International Union for the Conservation of Nature (IUCN) Protected Areas Definition, Management Categories and Governance Types https://portals.iucn.org/library/sites/library/files/documents/pag-021.pdf

existing MPAs. Because some existing MPAs have insufficient management to be classified as Medium Protection (e.g., they may continue to be unsustainably fished), the “Reference” scenario should be regarded as an ambition in which all existing MPAs are fully funded and can achieve a sustainable level of exploitation.

Table 1. Scenarios and descriptions for 30% MPA goals

Number	Scenario	Description
0	Reference	Assumes no future MPA expansion beyond what is currently in place. Existing MPAs are modeled to receive an adequate level of funding. Existing MPAs under High Protection retain this status. Existing MPAs that are not under High Protection are modeled to achieve Medium Protection.
1	High Protection	Assumes High Protection for all existing and expanded MPAs, both inshore and offshore, which includes upgrading all existing MPAs in Medium Protection to High Protection.
2	Mixed Protection	Assumes all existing MPAs keep their original status, while having 50% of the expanded MPAs to be under High Protection and 50% of the expanded MPAs to be under Medium Protection, both inshore and offshore.
3	Mixed-High Protection	Assumes 50% of the expanded inshore MPA to be under High Protection, 50% of the expanded inshore MPA to be under Medium Protection, and all expanded offshore MPAs to be under High Protection. It also assumes all existing MPAs that are not already under High Protection to be given Medium Protection status.

Methodology for Estimating Costs

To determine the overall cost of creating and managing MPAs, we analyzed the following categories of costs:

- *Establishment Costs:* One time or recurrent costs associated with establishing new MPAs (Ban et al. 2011), including planning for MPA placement, levels of protection and gazettement. This typically includes research, consultations, staffing, and in some cases compensation schemes.
- *Management costs:* Fixed and variable, recurrent annual or one-off costs of post-implementation management, and day to day activities, including the costs associated with operations, management, monitoring, and enforcing the MPA system over time (Balmford et al. 2004; Gravestock et al. 2008). In our models, and unlike Balmford et al. (2004) or Gravestock et al. (2008), high-level estimates for the costs of the entire system include central administration costs.

- *Opportunity Costs:* Forgone opportunity as the consequence of conservation interventions; often measured by reduction in profits and/or foregone revenue of industries or businesses as the result of an MPA being established. Opportunity costs may also consider livelihoods disruptions and less quantifiable losses to traditions and culture. Expected losses incurred by other sectors (Naidoo et al. 2006). This analysis considered the economic costs to the fisheries sector when fishing activity is relocated, regulated, or curtailed by a new conservation plan.

Methodology for Estimating Establishment Costs

For an estimate of the establishment costs of MPAs, we calculated the expected costs using the Binet et al. (2016) methodology. We applied multiple possible lengths of establishment periods for each protection scenario and reported the mean and variation in costs across each scenario. The number of MPAs were estimated by aggregating contiguous areas of the scenarios, dividing MPAs by those located inshore (largely within 12-nm of the coastline) and offshore (largely beyond 12-nm of the coastline).[5] In making this division, we avoided the potential case in which 30% of an EEZ could form a single contiguous MPA, since this would represent a potentially unjustified level of extrapolation from the data used in the original studies (Binet et al. 2016). Instead, we used the statistical expectation of the mean size of individual MPAs, given the size of the national MPA system. Establishment costs were then annualized over a 30-year amortization period, taking the bond rate of the 30-year U.S. Treasury Bill as the interest rate.

Methodology for Estimating Management Costs

To estimate management costs for MPAs in our sample of countries, we parameterized the statistical models developed by Waldron et al. (2020) using a largely confidential dataset generated and maintained by the United Nations Development Program (UNDP), in which a subset of national governments estimated the annual cost of adequately managing their national MPA systems, supplemented by other national reports not lodged with UNDP. Because the Waldron et al. (2020) models constitute privileged intellectual property, they are described briefly.

Despite showing high variability empirically, resource-need estimates per hectare were predicted statistically with 95% accuracy by the model. The best-fitting model included the following as predictor variables (Waldron et al. in preparation):

- The size of the system (which correlated strongly with the size of the individual MPAs).
- The level of economic activity on the coastline near the MPAs (GDP corrected for distance-to-MPA, which captures both the size of the coastal human population and the level of coastal economy activity).
- A metric showing the attractiveness of the fishing zones in the vicinity of the MPAs relative to other fishing sites in the same EEZ.

[5] Inshore and offshore were defined using i) the mean distance beyond the 12-nm limit in the empirical data used to generate the inshore costing algorithm; ii) 50 km offshore, which is larger than option (i) but based on a broad definition of how far small-scale or artisanal fishing vessels may travel; and iii) a smaller inshore area and larger offshore area than option (i)). See precise definitions of inshore and offshore in Waldron et al. (in preparation).

- The relative level of tourism expressed as international arrivals, over domestic population size. International arrivals data for 2017 (i.e., pre-pandemic) and domestic population size for the same year were both taken from the World Bank data.

Costs for Medium Protection MPAs are modeled as higher costs than High Protection MPAs, following expert assessments of the cost differences in managing inshore and offshore MPAs (Ban et al. 2011).

With modern advances in remote detection of fishing activity and the much smaller size of the industrial fleet (compared to the number of actors who might require management in a near-shore MPA), it is likely that offshore MPAs will have a different cost basis, and indeed be cheaper per hectare, than inshore ones. A further important point is that offshore protection strategies cannot necessarily function well for small-scale inshore actors, for example because smaller craft may not be under a legal requirement to carry the technology that allows them to be tracked by modern remote sensing systems (Ban et al. 2011). Therefore, management costing under this analysis calculated (a) inshore costs and (b) offshore costs as separate components of the total cost. Furthermore, the approach defined (c) the line offshore in the EEZ at which inshore approaches would end and offshore approaches would begin.

A recent extension of the Waldron et al. (2020) model also addresses the issue that, until recently, MPA systems largely fell inshore (within 12-nm of the coastline), whereas the MPAs under a highly ambitious expansion program will necessarily include large parts of the EEZ offshore (beyond 12-nm of the coastline). Extrapolation from empirical resource-need data is therefore likely to be inappropriate. More recent versions of the model therefore treat the inshore and offshore areas as separate problems (Waldron et al. in preparation).

To account for costs managing offshore MPAs, the model used evidence[6] from large MPAs and fishing zones enforcement efforts to estimate costs for the likely set of patrol craft, distance sensing of fishing vessels, and data analysis that would be needed for offshore MPAs. Full details of the management costs estimates can be found at Waldron et al. (in preparation).

Methodology for Estimating Opportunity Costs

Opportunity costs related to MPA systems considered in this analysis are the expected losses incurred by sectors or communities (Naidoo et al. 2006) when fishing activity is removed, regulated, or curtailed by a new MPA. While foregone future production for large- and small-scale fisheries represents only a portion of all opportunity costs of MPAs that regulate fish catches, it is considered one of the main opportunity costs, and therefore it is assumed this estimate provides a directional approximation of total opportunity costs for the purposes of this study.

To measure opportunity costs, we used two state-of-the-art Ocean Ecosystem Models (OEMs): Bioeconomic Marine Trophic Size-spectrum (BOATS) (Carozza, et al. 2016) and EcoOcean (Coll et al. 2020), to project the anticipated changes in fisheries catch and revenue over time.

[6] Some of the reference and case studies include: 1. Government of South Georgia and South Sandwich Islands 2013 Annual Report; 2. Coastal State Fisheries Management: A Review of Australian Enforcement Action in the Heard and McDonald Islands Australian Fishing Zone; 3. The Chagos Archipelago Patrol Vessel; 4. Food and Agriculture Organization of the United Nations (FAO), Recurrent & Operating Costs of Components.

For each of our three scenarios (plus the "Reference" scenario), we considered three possible futures related to fish stock health and climate change based on the Shared Socio-economic Pathways (SSPs) to examine different trajectories for the fisheries sector (Maury et al. 2017; Riahi et al. 2017; Coll et al. 2020) and Representative Concentration Pathways (RCPs) forecast by the Intergovernmental Panel on Climate Change (IPCC)[7] to examine projected climate impacts on ocean ecosystems.

These pathways reflect implicit assumptions about future fishing effort and future emission scenarios for climate forcing. Because the OEMs need to make certain assumptions about future climate forcings and future developments in the sustainability of fisheries practices, we created three sets of assumptions, based on a marine version of the SSPs as adapted by Maury et al. (2017). The three future marine pathways that we considered are as follows:

- *Optimistic – SSP1+ RCP2.6:* Assumes fishing effort is steered back to sustainable levels thanks to strong management and long-term considerations. The effort in 1974 is defined as the sustainable baseline, and in projections effort should return to 1974's levels by 2050. In EcoOcean nominal effort changes, while in BOATS effective effort changes.
- *Moderate – SSP3 + RCP7.0:* Assumes fishing effort increases due to poor management and short-term thinking, but rate of technological progress is low. Rate of effort increase is 1% per year, based on Rousseau et al. (2019). In both models, EcoOcean and BOATS, nominal effort changes.
- *Pessimistic – SSP5 + RCP8.5:* Assumes fishing effort is diversely affected by decreases in demand, poor management, and high technological progress. This complex development is implemented by fixing effort at the 2015 levels. In EcoOcean, nominal effort is fixed. In BOATS, effective effort is fixed.

Table 2 summarizes the complete set of model runs that we used to estimate opportunity costs.

Table 2 Scenario runs for the Ocean Ecosystem Models (OEMs)

Index	Scenario	Shared Socioeconomic Pathway (SSP)	Representative Concentration Pathway (RCP)	Run name
1	Reference	1	RCP2.6	S0ssp1rcp2.6
2	Reference	3	RCP7.0	S0ssp3rcp7.0
3	Reference	5	RCP8.5	S0ssp5rcp8.5
4	High Protection	1	RCP2.6	S1ssp1rcp2.6
5	High Protection	3	RCP7.0	S1ssp3rcp7.0
6	High Protection	5	RCP8.5	S1ssp5rcp8.5
7	Mixed Protection	1	RCP2.6	S2ssp1rcp2.6
8	Mixed Protection	3	RCP7.0	S2ssp3rcp7.0
9	Mixed Protection	5	RCP8.5	S2ssp5rcp8.5

[7] A Representative Concentration Pathway (RCP) is a greenhouse gas concentration trajectory adopted by the Intergovernmental Panel on Climate Change (IPCC).

10	Mixed-High Protection	1	RCP2.6	S3ssp1rcp2.6
11	Mixed-High Protection	3	RCP7.0	S3ssp3rcp7.0
12	Mixed-High Protection	5	RCP4.5	S3ssp5rcp8.5

To reflect the time taken to create expanded MPA systems, we modeled the expansion by linear interpolation at staggered times: half of the expanded MPAs were modeled to launch in 2025, and the remainder was modeled to launch in 2030.

OEMs were run at a resolution of one degree on a latitude-longitude grid of the oceans. Scenario designs were therefore upscaled from 1 km^2 to one degree, with parallel grid inputs showing the proportion of High Protection and the proportion of medium protection in each one-degree cell. We note that this has the advantage of not imposing exact locations on the MPAs, reiterating the intention that sovereign countries will retain control and flexibility in the final location of any MPAs.

The OEMs then projected the following economic outcomes at five-year intervals from 2020 to 2100:

- Catch biomass
- Catch value
- Catch per unit effort
- Net catch value (profit)

We calculated five-year values based on the average of the preceding five years. Overall, the OEMs runs are therefore harmonized to the highest degree possible. However, the independent nature of the two OEMs generates variation around these fundamental outputs by approaching the modeling in different ways (Christensen and Walters 2004; Christensen et al. 2015; Carozza et al. 2016; Galbraith et al. 2017; Coll et al. 2020).

Methodology for Estimating Benefits

We identified key benefits to marine protection to estimate the long-term and shorter-term positive impacts under the scenarios (“High Protection;” “Mixed Protection;” and “Mixed-High Protection”). The benefits analysis provided context to the costs analysis and provided insight into the long-term and shorter-term trade-offs inherent in various marine protection regimes.

Benefits were projected for 2030, 2040, 2050 and 2060, acknowledging that uncertainty increases considerably for decades further into the future. For all benefits, we took a marginal approach, measuring the additional "value of protection," defined as the change in economic outcomes that is projected to occur as a result of the expansion of the MPA system. All values are expressed in constant US dollars at 2015 values.

Two categories of benefits were considered:

- *Probabilistic Benefits:* Avoided economic loss in the future, in a probabilistic way. For example, if mangroves are not protected and exposed to ecosystem degradation, then storm surges could flood coastal fields and urban areas, causing costly damage to infrastructure and crops in a way that could have been avoided with better mangrove conservation (Brander et al. 2020). However, when working with a specific timeframe (2020-2060), we do not know when (or even if) those events will occur, and the benefit is therefore somewhat probabilistic.

- *Non-probabilistic Benefits:* In other cases, the benefit takes the form of a more concrete (non-probabilistic) boost to expected revenues, as occurs when the creation of a national park increases the flow of visitor income into the region (and potentially, into the national economy overall) (Weiler 2006; Fredman et al. 2007; Waldron et al. 2020). Fisheries benefits that can arise when stocks recover as a result of greater protection also take the form of concrete (non-probabilistic) changes in revenue (Brander et al. 2020; Sala et al. 2021).

Methodology for Estimating Coastal Protection Benefits from Mangroves

The value of the mangrove benefits was calculated using a meta-regression value transfer function (Hussain et al. 2011; Brander et al. 2020), combined with an estimate of the likely rate of loss of mangroves in the absence of protection (Brander et al. 2020).

To distinguish between High Protection and Medium Protection effects, we assumed that mangroves under High Protection have zero loss; and mangroves under Medium Protection have a rate of loss 50% lower than the baseline rate of loss. Medium Protection was further implemented in the meta-analytic value function by including the coefficient for provisioning services. This had the effect of reducing the overall value of the bundle of services because extractive use value trade-off against the value of regulating and cultural service, and the additional value of extractive use is outweighed by the reduced value of regulating and cultural services.

Because the carbon market for avoided emissions in mangroves is still limited (Hussain et al. 2011), mangrove-related benefits largely reflect the value of coastal protection and do not include possible carbon values. Nevertheless, global estimates of mangrove carbon suggest current market prices of US$10 per tonne, the hypothetical inclusion of mangrove forests carbon value would only increase projected mangroves benefits by approximately 10%.

Methodology for Estimating Coral Reef Tourism Benefits

Coral reefs also provide coastal protection (similarly to mangroves), but their principal value lies in driving forward the coastal tourism economy (Hussain et al. 2011; Spalding et al. 2017; Brander et al. 2020). This is especially true for the marginal effect of protection: an unprotected coral reef is still likely to reduce wave action, but it could have a much lower attractiveness to visitors than a protected coral reef. There are two ways in which protection may marginally alter visitor-based revenues around reefs: (1) the designation effect, (2) prevention of future degradation of the features attractive to tourism. Designation effects are well documented and can be more robustly modeled (Weiler 2006; Fredman et al. 2007). Creating new MPAs may increase visitor flows by simply increasing the average ability of a country's domestic or international visitor population to access high-quality coastal recreational areas. But more broadly, designation effects are driven by all the signalling, marketing and motivational impacts of formally declaring an MPA (Weiler 2006; Fredman et al. 2007). For example, scuba diving is one of the most high-value components of reef benefits (Spalding et al. 2017) and divers may be drawn to an MPA, not least because of the safety aspects of excluding powered vessels on the ocean surface.

Modeling degradation effects, on the other hand, would be highly speculative because the tourism economy is already economically dominant in many reef areas, and so it is unclear whether reefs not included in a newly expanded MPA system would lose visitors notably faster than reefs included in the system, especially over the three- to four-decade time period of this rapid study. We therefore focus on the designation effect.

The magnitude of the designation effect has been reported at approximately 10% to 25% (Weiler 2006; Fredman et al. 2007; Waldron et al. 2020). To capture the range of possibilities, we ran three analyses using three possible values of 10%, 16.5% and 23%. However, the effect is often measured in a local context, whereas benefit calculations in this study are at the national level. The local designation effect may overestimate the size of the boost to the national economy because new visitors may have chosen a different destination within the same country, and so the national effect is sometimes much smaller than the local or regional one. Additionally, there are few studies that assess whether the effect continues over decades (and it seems possible that it would diminish over longer time periods). To account for possible overestimation, we reduced the designation parameters by one-third. The one-third value should be regarded as illustrative because it is not possible to model displacement effects for consumer spending across the whole economy in a rapid assessment. However, we consider one-third to be *reasonable* (and still conservative), because many of the focus countries with reef-based economies were SIDS nations, where usually the opportunities for alternative, non-coastal expenditure in the visitor economy would be limited, and where international visitors drive the tourism economy. For international visitors, the designation effect would be more strongly preserved because the alternative targets of expenditure often lie in different countries (tourist destinations), thus reducing the national-scale opportunities for spending displacement. To distinguish between Medium Protection and High Protection, we assumed that the (reduced) substitution effect in Medium Protection MPAs was 50% of the estimated effect for High Protection MPAs.

Visitor values will increase as overall tourism increases into the future, and so for each of the years projected (i.e., 2030, 2040, 2050 and 2060), we used a two-step process where we multiplied the current estimated visitor value by the percentage increase in international arrivals expected in the interval between the present and each future year, and then applied the designation-effect parameter to the result (Waldron et al. 2020). If, in the future, countries increase either their capacity to capitalize on their protected natural capital (e.g., by improved tourism facilities) or reduce their consumer surplus (by pitching the costs of visiting MPAs closer to what the market would bear), then future benefits would be larger than we estimate by this method.

Methodology for Estimating Industrial and Artisanal Fisheries Benefits

For fisheries benefits, we focused on the change in landings value (the economic value of all wild-caught fish landed). This benefit arises when the landings value after MPA expansion exceeds the landings value expected in the absence of MPA expansion. However, the impact of MPA expansion can be both positive and negative, and indeed switch from negative to positive over time, raising a potentially difficult question of whether some form of net benefit should be calculated instead.

Consistent with our costing methodology, the fisheries benefits (both positive and negative) are derived from BOATS, a model that takes the pattern of fisheries restrictions in each gridded EEZ (one-degree resolution grid), then uses a complex set of biological and economic sub-models to project the future patterns of fish stocks, fishing efforts and fisheries economic outputs from 2020-2100. Because we are comparing the estimated benefits with the estimated costs, and foregone landings value is already considered an opportunity cost, we chose to focus exclusively on cases where the change in landings value was positive, treating all non-positive outcomes as zero. Medium Protection MPAs were modeled as having 50% of current fishing effort (as a proxy for sustainable fishing), whereas High Protection MPAs were modeled as allowing no fishing.

Input-output Multipliers

The revenue increases that result from revenue-generating marginal effects in expanded MPA systems give an incomplete picture of the full benefit. In any revenue-generating industry that expands, the increased income to the industry has upstream and downstream effects that add further output to the regional and national economy. For example, if a new MPA attracts additional visitors, who then spend more in the local hotels and restaurants, the supply chain for those hospitality venues will also experience an increased in business and income. There will be a general rise in both the staff employed and the income that those staff have to spend, leading to an induced increase in spending in all other businesses in the economy. Each additional dollar of output in the tourism sector can therefore create more than one additional dollar of additional economic output in the economy. The ratio between the marginal increase in immediate or "direct" output (here, the tourism-specific output) and the marginal increase in total output is referred to as a "multiplier", and this quantity varies across countries and sectors. For fisheries, we applied the multipliers from Lam et al. (2016). For coral reef tourism, we calculated multipliers using the regression model of Van Leeuwen et al. (2009), taking the projected population size in 2030 from World Bank data for population estimates and projections (World Bank, 2013) setting the "sun" factor to 1 and assuming that the publication year was 2015 (noting that this last assumption led to a conservative estimate of the tourism multipliers, since multiplier values declined with year of publication in that 2009 study, and 35 such declines may create a decline magnitude that is biased on the large side). For avoided loss values such as those in the mangrove value transfer function, multipliers are not usually calculated and so we set them to 1.0.

Methodology to Aggregate all Benefits

The three types of benefits were added together to estimate the total projected benefit (at least, the total for the subset explored). To explore the range of variation around these summed benefit projections, we particularly focused on three options: (1) low estimate, in which the designation effect takes the smallest value for tourism-based benefits and fisheries benefits taken from marine SSP5; (2) medium estimate, using the middle-ranking parameter value for the designation effect and fisheries benefits taken from marine SSP3; (3) high estimate, using the highest parameter value for the designation effect and fisheries benefits taken from marine SSP1. Mangrove value transfer functions did not generate a range and are therefore identical in all three options.

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