Sea Change: Costs and Benefits of Marine Protected Areas

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Cover: Underwater scenery at Two Tree dive site in Raja Ampat, Indonesia © *Purwanto Nugroho/TNC Photo Contest 2019*

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Introduction

Two endangered green sea turtles on Lady Elliot Island © *Jordan Robins /TNC Photo Contest 2019*

Introduction

In the face of decades of human-induced biodiversity loss exacerbated by the climate crisis (Diaz et al. 2019; IPCC 2022), the Convention on Biological Diversity's (CBD's) Global Biodiversity Framework (GBF) calls for bold 2030 targets and a transformational plan to see humanity living in harmony with nature by 2050.[1,2] A critical milestone to achieving the GBF is the 30x30 agenda — a campaign to catalyze collective action to conserve at least 30% of Earth's land, freshwater and ocean realms by 2030.[3] Area-based conservation is a principal mechanism to achieve these goals and includes both nationally recognized terrestrial and Marine Protected Areas (MPAs), and Other Effective Area-based Conservation Measures (OECMs) — a recently defined policy mechanism recognizing locally managed areas that sustain biodiversity outside of formal protections[4] (Gurney et al. 2021). With over 100 countries[5] signed onto the 30x30 agenda, momentum is building to expand area-based conservation globally. Some countries are already translating this ambitious agenda into their own domestic policies by committing to conserve 30% of their national domains by the end of the decade.[6]

A known obstacle to achieving these ambitious conservation goals is durable and sufficient funding (Deutz et al. 2020). Recent research estimates that meeting global biodiversity targets will require about US$300–967 billion annually (Brander et al. 2020), with the total global annual flow of funds toward biodiversity protection estimated at only US$124–143 billion[7] (Deutz et al. 2020). In addition, historically high debt burdens exacerbated by the COVID-19 pandemic and the current economic downturn (Bulow et al. 2020) further challenge funding streams for biodiversity conservation. As countries prioritize ocean conservation and blue economy strategies, they look to mobilize resources from a variety of domestic and international sources (McCrea-Strub et al. 2011; Bohorquez et al. 2022). Effective funding, planning, implementing, and managing of the marine environment thus requires economic assessments of the costs and benefits of area-based management (Hoagland, et al. 1995; Sanchirico, et al. 2002).

Over the last decades, research has synthesized and estimated the costs of establishing (e.g., McCrea-Strub et al. 2011), managing, and enforcing MPAs (Figure 1; e.g., Ban et al. 2011; Davis et al. 2015; Sala et al. 2016) at local to global scales (e.g., Balmford et al. 2004; Cullis-Suzuki and Pauly 2010).

1 CBD 2021 Post-2020 GBF. https://www.cbd.int/conferences/post2020
2 IUCN Post 2020. https://www.iucn.org/sites/default/files/2022-07/iucn-issues-brief_post2020_jul22.pdf
3 Campaign for Nature. https://www.campaignfornature.org/news/category/30x30
4 Other Effective Area-based Conservation Measures (OECMs) are an alternative to traditional protected areas, in that they can include any geographically defined area that has a management structure and can show a long-term positive impact on biodiversity (IUCN 2019). CBD 2018 decision 14/8 Protected areas and OECMs. https://www.cbd.int/doc/decisions/cop-14/cop-14-dec-08-en.pdf
5 This number includes members of the Global Ocean Alliance, High Ambition Coalition for Nature and People, and High-Level Panel for a Sustainable Ocean Economy.
6 See https://www.gov.uk/government/publications/g7-climate-and-environment-ministers-meeting-may-2021-communique/g7-climate-and-environment-ministers-communique-london-21-may-2021#environment
7 Deutz et al. 2020) – Figure 1. Global biodiversity conservation financing estimates for 2019. Source of funding include domestic budgets and tax policies (~57%), natural infrastructure (~20%), biodiversity offsets (~6%), official development assistance (~5%), sustainable supply chains (~5%), green financial products (4%), philanthropy and not-for-profit organizations (2%), and nature-based solutions and carbon markets (1%).

Mariko Wallen and Louis Godfrey harvest seaweed on their farm in Placencia, Belize. © *Randy Olson*

Researchers have used surveys to examine the required income for MPAs to achieve management objectives (Gravestock et al. 2008). They have used bioeconomic models to understand the economic value of MPAs (White et al. 2008; Sala et al. 2013), the benefits and opportunity costs of MPAs to fishing economies (Sumaila et al. 2007; Sumaila et al. 2015) and the political economy (Smith et al. 2010), and trade-offs associated with MPAs for different sectors or communities (e.g., Davies et al. 2018; Sala et al. 2021). Despite these research advances, information on costs is rarely published publicly, and reporting is inconsistent and not standardized across contexts and geographies (Iacona et al. 2018; White et al. 2022). Further, the costs and potential benefits of area-based expansion are topics that have received limited attention at scales relevant for national decisions and policy commitments (Gravestock, et al. 2008; Davis et al. 2019; Brander et al. 2020).

Building on the foundational work of Balmford et al. (2004), two recent papers addressing global costs are Brander et al. (2020) and Waldron et al. (2020). Brander et al. estimated the global costs and benefits of no-take MPAs to evaluate the economic case for expansion. Waldron et al. assessed the costs, benefits and economic implications of protecting 30% of the planet. They found that an average annual investment of US$140 billion in protected areas (marine, terrestrial, and freshwater) through 2030 could lead to US$250 billion in increased economic output annually, and approximately US$350 billion in improved ecosystem services annually, compared with the status quo. These findings provided timely guidance for framing global conservation policy agendas through the lens of their economic costs and expected benefits. In doing so, they also activated a discussion on the importance of being more explicit about who benefits and who incurs the costs of expanded area-based conservation — elevating the critical role of Indigenous Peoples and local communities,[8] OECMs and traditional ecological knowledge and management in the achievement of this agenda (Simmons et al. 2021; Dudley and Stolton 2022). As OECM frameworks are relatively new and still in the process of being registered and implemented, their costs and benefits are difficult to ascertain currently, but we can assume data will be forthcoming as OECMs contribute toward the 30x30 agenda (Estradivari et al. 2022). Thus, for the purpose of this discussion, we rely solely on the best available data accessible for MPAs.

Global cost and benefit estimates of biodiversity conservation and MPAs are important because they can inform the global community (e.g., United Nations agencies, funders, sectors, communities, conservation practitioners, non-governmental organizations (NGOs) and policymakers) about the magnitude of resources required for durable marine conservation and can spur action (Brander et al. 2020). However, governments also need country-level estimates of the costs and benefits of marine protection to assess and seek appropriate funding. The Nature Conservancy has developed a number of different financing mechanisms to help countries achieve marine conservation agendas.[9] Through this work, it became apparent that having plausible estimates for a range of costs and benefits of 30% area-based conservation is critical for negotiating and structuring sustainable financing solutions. To generate adequate cash flows into durable conservation strategies, an informed sense of the economic feasibility of area-based conservation targets in the early stages of negotiation is important. This also helps generate buy-in from cross-sector ministries and impacted stakeholders and communities who will engage in the subsequent place-based national or subnational Marine Spatial Planning (MSP) processes.

To expand and build on previous studies on MPA costing, fill knowledge gaps, and support policy makers, practitioners, and funders to better understand the possible financial implications of setting ambitious ocean protection commitments, The Nature Conservancy convened economists, finance specialists, scientists, and MSP experts to adapt the global cost and benefits framework developed by Waldron et al. (2020). As a rapid, exploratory exercise, we used scenario modeling to assign different levels of protection in the creation of new MPAs, the strengthening of existing MPAs, and the prediction of future ocean ecosystem conditions to estimate high-level ranges of the potential costs and benefits of protecting 30% of individual countries' marine waters (Waldron et al. in preparation). We applied this approach to a subset of 64 countries identified from our Blue Bonds for Ocean Conservation Strategy[10] that are geographically representative, and that ensure the analysis best reflects the likely costs and benefits of MPAs in a range of countries, including those in temperate and tropical regions, with low and high incomes, and with high dependence on fisheries and/or tourism. We used existing data on MPA costs and benefits that are well established and do not present comprehensive results on the full suite of considerations that should be incorporated into these discussions with stakeholders.

8 An Open Letter to the Lead Authors of 'Protecting 30% of the Planet for Nature: Costs, Benefits, and Implications.' https://openlettertowaldronetal.wordpress.com/

9 TNC's Blue Bonds for Ocean Conservation. https://www.nature.org/en-us/what-we-do/our-insights/perspectives/an-audacious-plan-to-save-the-worlds-oceans/

10 TNC's Blue Bonds for Ocean Conservation Strategy unlocks durable ocean protection funding by refinancing sovereign debt, which can reduce a country's outstanding debt, lower interest rates, and secure longer repayment periods (McGowan et al. 2020). The debt conversion leads to savings for the government that in turn are applied to the creation of a marine spatial plan, provide grant funding, and can endow a conservation fund to support local ocean conservation to protect, manage and restore marine biodiversity, conserve important species and safeguard ecosystem service-provisioning habitats such as mangroves and coral reefs. TNC may support governments by (1) conducting and structuring the debt conversion, (2) setting up the conservation fund, and (3) lending its scientific, technical, and planning expertise to design and facilitate participatory MAP processes with active stakeholder and rightsholder engagement to expand marine protections and identify areas for sustainable economic activity. See Supplemental Materials, available at https://www.nature.org/en-us/what-we-do/our-insights/perspectives/marine-protected-areas-global-biodiversity-framework/, for more information on these countries.

Marine wildlife swim around a shallow water coral reef. *© Lorenzo Mittiga /TNC Photo Contest 2019*

The purpose of this analysis was to develop an applied approach that informs TNC's Blue Bonds for Ocean Conservation Strategy, and to share our findings in support of the CBD's GBF and 30x30 agenda. This analysis is specifically relevant for countries interested in applying 30% marine protection commitments at the national level. We summarize our findings based on income groupings and area required to meet 30% coverage goals. The estimates provided are a starting point for early-stage efforts to develop resource mobilization strategies to improve ocean protection and management. They can also be used to identify and negotiate a mix of resources to recruit external funding (McCrea-Strub et al. 2011; Roth et al. 2019; Deutz et al. 2020; Jänes et al. 2020; Sumaila et al. 2021). The findings underscore the importance of developing harmonized costing frameworks and data and making these data accessible to countries and governments seeking to increase marine protection or to mobilize resources for global commitments to protect biodiversity. We also emphasize that all conservation costing approaches, and the distribution of their impacts and benefits (Balmford and Whitten 2003) should be further refined through inclusive MSP processes to locate protection areas and improve management systems (Woodhouse et al. 2015; Flannery et al. 2016; Narayan et al. 2016; Allison et al. 2020; Cisneros-Montemayor et al. 2020; Kockel et al. 2020; Vierros et al. 2020).

Estimating the Costs and Benefits of Different Protection Scenarios

Mackerel fishermen in the Seychelles fish along the shore with small boats and seine nets, trapping fish in the shallows and hauling the catch up onto the sand. © *Jason Houston*

Estimating the Costs and Benefits of Different Protection Scenarios

The methods and analyses draw on and update previous work by Waldron et al. (2020). Additional methods information can be found in the Supplemental Materials with full details of the costs and benefits estimates available in Waldron et al. (in preparation).

Three scenarios were created from which to model protected area expansion for an individual country, up to 30%. Two levels of protection were assumed (high protection: non-extractive uses, and medium protection: sustainable uses), and different treatments of the existing MPAs were applied (Table 1). These rules are reflected in the scenario names: "High Protection," "Mixed Protection" and "Mixed-High Protection" (see Table 1 for rule descriptions). These scenarios are compared with a single "Reference" scenario which is used as a baseline of the existing MPA network from which to quantify the impact of 30% expansion (World Database on Protected Areas (WDPA) 2021). We acknowledge that not all future area-based conservation will be in the form of MPAs. OECMs, community-based areas and Locally Managed Marine Areas (LMMAs) will make important contributions toward area-based targets. For simplicity, we use the term MPAs inclusively and assume it encompasses alternative forms of area-based conservation with equivalent medium and high protection levels (Gurney et al. 2021).

Spinecheek anemonefish, photographed in the waters at Kofiau Island, Raja Ampat Islands, West Papua Province, Indonesia © *Jeff Yonover*

TABLE 1: SCENARIOS AND DESCRIPTIONS FOR 30% MPA GOALS. *Overview of the scenarios developed for the model, including the treatment of existing MPAs, allocation rules across ocean domains (inshore and offshore) to reach the 30% protection target, and methods for estimating establishment, management and opportunity costs and benefits to industrial and small-scale fisheries using forecasting approaches in ocean ecosystem models.*[11] *There is a baseline scenario ("Reference") as well as three scenarios ("High Protection," "Mixed Protection" and "Mixed-High Protection") to model 30% expansion for each of the 64 countries in the analysis. The descriptions are in terms of the existing MPAs and the percentage of high protection and medium protection as inshore and offshore MPA expansion contributing to the 30% protection target.*[12]

SCENARIOS				
	0. REFERENCE	**1. HIGH PROTECTION**	**2. MIXED PROTECTION**	**3. MIXED-HIGH PROTECTION**
EXISTING MPAs	High Protection MPAs remain the same. Other MPAs move to Medium Protection. All protection is assumed to be adequately funded.	All MPAs are upgraded to High Protection.	All MPAs keep original status.	All existing offshore MPAs are upgraded to High Protection. Other MPAs keep original status.
INSHORE MPA EXPANSION CONTRIBUTING TO 30% PROTECTION TARGET	NA	All High Protection	Half High Protection Half Medium Protection	Half High Protection Half Medium Protection
OFFSHORE MPA EXPANSION CONTRIBUTING TO 30% PROTECTION TARGET	NA	All High Protection	Half High Protection Half Medium Protection	All High Protection
MPA EXPANSION ESTABLISHMENT COSTS	NA	Derived from Ban et al. (2011) and Binet et al. (2015) and based on a confidential dataset of MPA funding requirements collected by the United Nations Development Programme from governments around the world		
MPA MANAGEMENT COSTS	Adequate funding is assumed for the existing MPAs	Applied different costing models to inshore and offshore domains according to the following variations of inshore: 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)		
OPPORTUNITY COSTS AND BENEFITS	All scenarios were forecasted according to three combinations of Shared Socioeconomic Pathways (SSP) and climate forecasting Representative Concentration Pathways (RCPs) assumptions: i) OPTIMISTIC: SSP 1 + RCP 2.6 Assumes sustainable fishing with nominal fishing effort change and climate forecasting stays within 2-degree Celsius range ii) MODERATE: SSP 3 + RCP 7.0 Assumes increased fishing effort with significant challenges to climate mitigation and low technological advancement iii) PESSIMISTIC: SSP 5 + RCP 8.5 Assumes fishing effort is diversely affected by decreases in demand, high technological advancement and poor management			

11 Shared Socioeconomic Pathways (SSPs) and Representative Concentration Pathways (RCPs) used in the United Nations Framework Convention on Climate Change (UNFCCC) climate forecasting. https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_annex-i.pdf

12 Scenario detailed description: The "Reference" scenario does not have any expansion of MPAs: High Protection MPAs remain the same while the other MPAs move to Medium Protection. All protection is assumed to be adequately funded. Under the "High Protection" scenario, all existing MPAs are upgraded to high protection, and 100% of the inshore expansion is assumed as high protection, and 100% of the offshore expansion is assumed as high protection. Under the "Mixed Protection" scenario, all existing MPAs keep their original protection status, while having 50% of inshore expansion as high protection and 50% of inshore expansion as medium protection, and 50% of offshore expansion as high protection and 50% of offshore expansion as medium protection. Under the "Mixed-High Protection" scenario, all existing offshore MPAs are upgraded to high protection, and others are kept with their original status, while having 50% of inshore expansion as high protection and 50% of inshore expansion as medium protection, and 100% of offshore expansion as high protection. See Supplemental Materials for more information on the scenarios.

These scenarios were applied to a subset of 64 countries that were curated based on enabling conditions identified from TNC's Blue Bonds for Ocean Conservation Strategy. Those enabling conditions include debt to Gross Domestic Product (GDP) ratios, political interest in 30x30 ocean commitments, and/or potential to mobilize financing (see Supplemental Materials).[13]

The costing models were parameterized using a confidential dataset generated and maintained by the United Nations Development Programme (UNDP).[14] The confidential nature of the dataset restricts our ability to publicly disclose the complete findings, and thus the data are anonymized and summarized for public review. Note that we are able to share findings in bilateral discussions with the specific countries whose information has been analyzed. We organize and anonymize data for costs and benefits by country income group to aggregate similar economies; we provide ranges for low-income, low-middle-income, upper-middle-income and high-income based on the World Bank categorization of income groups. It is important to note that our country set skews heavily toward Small Island Developing States (SIDS) because our objective is to ensure the potential applicability of our sustainable debt mechanisms.

ESTIMATING COSTS FOR MPAs

To understand the average annual costs of establishing and maintaining scenarios for a 30% MPA system (Table 1),[15] we consider three categories of costs: establishment costs, management costs, and opportunity costs. For comparability, costs are estimated in 2015 US dollars so that the UNDP data can be applied consistently across all countries in the model (Waldron et al. in preparation).

13 Not all countries met all conditions. Conditions subject to change. Inclusion in the list does not mean sovereign debt restructuring is possible.

14 Data were collected by the UNDP on the basis they would remain confidential. Estimates provided by governments and their agencies on the optimal level of budget for their national MPA systems (as distinct from the current level of budget). The majority of these estimates are derived from the Financial Score Cards (digital.library.unt.edu/ark:/67531/metadc226724/m1/1/) submitted to the UNDP, where governments or their agencies calculate their own estimates, which then pass through a validation review as part of a standardized, formal assessment of their MPA funding needs. A minority of data were sourced from individual government and agency reports not part of the scorecard submissions; see Waldron et al. (2020) for details.

15 The cost estimates are useful for improving financing for existing MPAs ("Reference" scenario) because many are largely underfunded and therefore the total costs include increased existing MPA budgets to ensure optimal protection can be achieved in addition to establishing adequately resourced new MPAs.

During a free dive, a photographer snapped this picture of a manta ray as it passed overhead, accompanied by an entourage of juvenile golden trevally, on the Ningaloo Reef in Western Australia. © *Jake Wilton/TNC Photo Contest 2022*

Typology of Costs Associated with MPAs

ESTABLISHMENT COSTS

One-time or recurring costs associated with planning for MPA placement, levels of protection and gazettement.

Administrative
Staff and Salaries | Trainings | Overheads or Office Acquisitions

Planning
Stakeholder and Community Engagement Workshops
Science and Research | Communications and Outreach
Legal Framework Development| Management Plan Development

Compensation
Alternative Income-Generating Activities
Buy-Outs and Short-Term Compensation

MANAGEMENT COSTS

Fixed and variable, recurring annual or one-off costs of post-implementation management and day-to-day activities.

Operations
Fuel | Outreach and Education | Capital Expenses Such as Vehicles, Vessels, and Maintenance of Infrastructure | Ecological Restoration, Recovery or Maintenance

Administrative
Staff and Salaries | Trainings | Overheads

Compliance and Enforcement
Chartering or Buying Enforcement Vessels (Boats or Aircraft)
Legal Systems: Investigations, Fees and Prosecutions

Science and Research
Monitoring | Research Activities

OPPORTUNITY COSTS

Forgone opportunity as the consequence of conservation interventions; often measured by reduction in profits and/or forgone revenue of industries or business as the result of an MPA being established. Opportunity costs may also consider livelihood disruptions and less quantifiable losses to traditions and culture.

Direct Revenue Generation Losses

Forgone Opportunities for Job Creation

Losses to Tradition and Culture

Multigenerational Displacement of Livelihoods

FIGURE 1: ARRAY OF POTENTIAL COSTS ASSOCIATED WITH INCREASING MARINE PROTECTION

Typology of Benefits Associated with MPAs

BENEFITS TO ECOSYSTEMS

Indirect benefits that support ecosystem functioning and services, contribute to the survival of species and foster biodiversity and resilience to climate change impacts. These are typically non-monetary benefits.

Species Persistence and Survival

Improved Ecological Condition of Habitats
Coral Reefs | Mangroves | Kelp and Seagrasses

Climate Refugia for Species under Climate Change
Ecosystems that provide less hostile habitat for key species under conditions of climate warming

BENEFITS TO PEOPLE AND COMMUNITIES

Direct and indirect benefits to people through their consumption and transformation of ecosystem goods and services that provide livelihoods and secure well-being.

Protection from Natural Disasters Such as Storms, Sea-Level Rise, and Coastal Erosion and Tsunamis

Carbon Storage in Mangroves, Seagrasses, Kelp and Sediments as Natural Climate Solutions

Food Security and Nutrition

Preservation of Cultural Values and Ocean-Related Livelihoods

BENEFITS TO INDUSTRIES

Direct benefits from revenues related to the blue economy enhanced by MPAs or indirect benefits from reduced or avoided losses to infrastructure from storms and adverse weather events.

Tourism
Revenues from hotels and restaurants, recreational fishing, diving, snorkeling and boating

Fishing Revenues
Revenues from sales of commercial fish

Employment and Commerce from Linked Sectors
Jobs in tourism, aquaculture and fishing

Reduced Loss to Grey and Infrastructure Buildings
Reduced private and public sector costs of repairing bridges, roads and buildings, water and sanitation

FIGURE 2: ARRAY OF POTENTIAL BENEFITS ASSOCIATED WITH INCREASING MARINE PROTECTION[16]

16 Not all costs and benefits included in Figure 1 and Figure 2 could be considered in this analysis. We describe in each section below the subset of costs and benefits that we were able to estimate.

Establishment Costs

Establishment costs are the expenditures necessary to create MPAs in national waters. They are one-time or recurring costs and include administration, planning, and potentially compensation schemes (Figure 1; McCrea-Strub et al. 2011; Davis et al. 2019). Establishment costs vary based on the number, location, and size of MPAs created, and the length of the establishment periods (in practice this can be years to decades of planning) (Jumin et al. 2018; UNESCO 2021).

We based our establishment costs estimates on existing calculations by Binet, et al. (2015) and Ban et al. (2011) and calculate a mean establishment cost for income groups. All costs considered to calculate establishment costs are represented in Figure 1. For each, we provide a high estimate (at 5% interest, assuming that these costs may be paid with borrowed money) amortized over 30 years; and a low estimate (set at 0% interest). We also provide estimates from our own experience budgeting for MSP processes that are inclusive and ensure engagement with and input from stakeholders.

Management Costs

Management costs can be considered as the fixed, variable, one-off or ongoing costs associated with administering and enforcing MPAs over time. These can include operations and capital expenses, administration, compliance frameworks, potential compensation or ongoing subsidies, and science and research for monitoring (Figure 1; Balmford et al. 2004; Ban et al. 2011). Because management costs are different for inshore areas (coastal MPAs) and offshore areas (MPAs beyond 12 nautical miles; see Table 1 for sensitivity to this assumption), we applied different cost modeling approaches for MPAs in each domain[17] (Waldron et al. 2020). All costs considered to calculate management costs are represented in Figure 1.

For each scenario, we modeled a range of annual management costs and tested the sensitivity to two parameters of the costing algorithms: (1) the definition of inshore versus offshore (as defined in Table 1), and (2) the cost difference when mixed zones are present in the network (a combination of both high and medium protection levels). This cost differential is driven by the additional need to monitor and enforce MPAs that allow fishing versus those that do not. Three cost differentials were used based on Ban et al. (2011). Thus, each of our scenarios had a range of nine different management cost estimates: three for the inshore/offshore parameter, times three for the mixed-use cost parameter.

For inshore costing we use a predictive statistical model that reflects the costs of managing marine areas with coastal economic activities such as small-scale fishing and tourism, along with the associated need for staff, boats, and lodging if required (Waldron et al. 2020). These empirical data came from management budgets from 30 countries in the global database[18] and other sources (Waldron et al. in preparation). The majority of empirical data on optimal budgets for national MPA systems referred to above come from a period (mostly the mid-to-late 2010s) when national systems were located in zones that would be defined as "inshore" in this study. The statistical model predicted with ~90% accuracy (e.g., ~90% of the variation was explained), giving confidence in its suitability for conservation application, with the main predictors being the size of the MPA system area, distance from the shore, coastal GDP, reported fishing effort, and the level of international tourist visits (relative to the domestic national population). Full model specification is available in Waldron et al. (in preparation).

Offshore MPA management costs focus primarily on industrial or semi-industrial fishing, whereas inshore management can be more costly because it often includes more intensive control of tourism and other small-scale coastal activities. For the offshore approach, we analyzed the limited literature on offshore MPA management costs, particularly for offshore fisheries enforcement (Rowlands et al. 2019), and the cost of deploying remote monitoring systems such as Automatic Identification Systems (AIS) and Remote Electronic Monitoring (REM).

Opportunity Costs

In the context of protected areas costing analyses, Naidoo et al. (2006) defined opportunity costs as the expected losses incurred by sectors or communities when an activity is removed, regulated, or curtailed. In this project, we are using this definition of opportunity costs in relation to new MPAs. In the marine environment, opportunity costs from changes in protection are most commonly loss of revenue resulting from banning or limiting fishing within an MPA (Ban and Klein 2009) but can include other ocean uses (Gissi, et al. 2018) and industries such as tourism, aquaculture, shipping, and mining, for example. Importantly, some opportunity costs can be non-monetary and include cultural and sacred values associated with marine access and resource use by Indigenous Peoples and communities (Ban and Frid 2018). In this paper, all cultural and sacred rituals that take place within MPAs, such as recognizing the seasons, worshipping, and wayfinding (Ban and Frid 2018; Buscher et al. 2021) are considered compatible with both levels of protection.

17 These domain variations correspond to three limits to the extent of the inshore management area defined as (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 the Supplemental Materials for full details).

18 Data were collected by the UNDP on the basis they would remain confidential. Estimates provided by governments and their agencies on the optimal level of budget for their national MPA systems (as distinct from the current level of budget). The majority of these estimates are derived from the Financial Score Cards (digital.library.unt.edu/ark:/67531/metadc226724/m1/1/) submitted to the UNDP, where governments or their agencies calculate their own estimates, which then pass through a validation review as part of a standardized, formal assessment of their MPA funding needs. A minority of data were sourced from individual government and agency reports not part of the scorecard submissions; see Waldron et al. (2020) for details.

Our estimates of opportunity costs only include the near-term economic impacts and forgone revenue for both industrial and artisanal fisheries, and do not consider other opportunity costs (e.g., forgone development).

Depending on the habitat and species, a documented benefit for MPAs to fisheries is that fish stocks recover inside the MPAs and spillover occurs (Roberts et al. 2001; Abesamis and Russ 2005; Kellner et al. 2008; Pérez-Ruzafa et al. 2008; Halpern et al. 2009; McCook et al. 2010). However, once legal enforcement begins, MPAs can result in initial declines in catch volume and revenue if the MPA overlaps with fishing locations and fisheries are displaced or removed altogether. Evaluating the potential benefits to fish stocks, and in return on fishing sectors over time, is computationally demanding and requires linking potential zoning designs with life history elements of species populations, human activities, and dynamic ecosystem models which may incorporate climate forecasts (e.g., Metcalfe et al. 2015; Lam et al. 2016; Waldron et al. 2020). For this project, to estimate the initial opportunity costs to fisheries in terms of biomass and income losses, and how these trends change over time,[19] we applied two Ocean Ecosystem Models (OEMs): Bioeconomic Marine Trophic Size-Spectrum (BOATS) (Carozza et al. 2016) and EcoOcean (Coll et al. 2020).

These models treat fishing effort with the following assumptions: at MPA implementation, fishers "follow the fish," meaning it is assumed fishing will be the highest where biomass is the highest. At MPA implementation, fishers stop fishing in high protection MPAs, and start fishing at sustainable levels in medium-protection MPAs. In all cases, although the fishing effort is not allowed to change freely anymore, the amount of catchable fish biomass will change across the ocean, depending on oceanographic conditions and fishing pressure. This will result in changes in catch that eventually track oceanographic conditions.

To estimate immediate and future opportunity costs, we considered several pathways for factors that influence climate change and global fisheries recovery or depletion.[20] The OEMs are calibrated to reflect the potential future state of the ocean and its uses. To do this, we used three different combinations of 1) Shared Socioeconomic Pathways (SSPs) to examine different trajectories for the fisheries sector (Maury et al. 2017; Riahi et al. 2017; Coll et al. 2020) and 2) representative concentration pathways (RCPs) forecast by the Intergovernmental Panel on Climate Change (IPCC)[21] to examine projected climate impacts on ocean ecosystems. These models were applied to all scenarios, including the reference scenario for comparisons. See Supplemental Materials for greater explanation on these assumptions.

ESTIMATING THE ECONOMIC BENEFITS OF MPAs

Much of the academic literature and evidence to support MPAs typically focuses on the increased fisheries revenues from improved catch as a primary benefit of area-based conservation (Brander et al. 2020; Trégarot et al. 2020; Sala et al. 2021). For the last decade or so, newer approaches have focused on the economic benefits or values delivered from ecosystem services such as coastal protection, reef and mangrove enhancing services to coastal fisheries, and blue carbon and tourism, to name a few.[22] These regulating and provisioning services can deliver both monetary and non-monetary benefits to local communities and economies.

Measuring the total economic benefits that may flow from MPAs is a significant undertaking at any scale. Frameworks are being developed and refined, but knowledge gaps remain, especially for MPAs in pelagic waters, comprehensive valuation of marine and coastal ecosystem services, and the economics of data-poor fisheries. Thus, we focused the following analysis on three well-documented benefits whose data can be disaggregated to specific countries: 1) coastal protection from mangroves, 2) coral reef tourism, and 3) industrial and artisanal fisheries (Roberts et al. 2001; Russ et al. 2004; Sumaila et al. 2015; Carlson et al. 2021). Like our costing analysis, the benefit calculations provide only a partial snapshot of the full range of positive impacts that might flow from conservation investments over time. We recognize the importance of other benefits delivered from ocean conservation, such as safeguarding global marine biodiversity, improving ecological condition, regulating carbon and nutrient cycling, and the localized benefits of a healthy ocean to communities, industries, culture, and ecosystems (Selig and Bruno 2010; Sala et al. 2021), but we were unable to account for all potential benefits of area-based conservation in this analysis.

19 The opportunity costs to fisheries are forecast to 2100 per climate modeling trajectories.
20 The Ocean Ecosystem Models (OEMs) were run to project the following economic outcomes at five-year intervals from 2020 to 2100: catch generated (in terms of biomass), catch value, catch per unit of effort, and net catch value or net revenue.
21 A Representative Concentration Pathway (RCP) is a greenhouse gas concentration trajectory adopted by the Intergovernmental Panel on Climate Change (IPCC).
22 See Mapping Ocean Wealth for examples. https://oceanwealth.org/

We calculated the marginal benefit of expanding MPAs to 30% protection under our three MPA scenarios using the reference scenario for comparison (Table 1). We documented low-, medium-, and high-benefit estimates for 2030, 2040, 2050 and 2060. While projections continue to 2100, we do not report beyond 2060 due to model uncertainty for subsequent decades. Our benefits estimation only included direct benefits from fisheries and tourism, and indirect benefits from coastal protection and avoided infrastructure loss linked to mangroves. We also applied multipliers based on Lam et al. (2016), similar to work by Fredman et al. (2007), Van Leeuwen et al. (2009), and Spalding et al. (2017) to estimate broader benefits to the national economy, including the effects of increased revenues for coastal tourism, fisheries, and related sectors. Several papers also report multipliers and spillovers from improved management that are in line with these projected impacts (Martinet et al. 2007; Van Leeuwen et al. 2009; Cámara and Santero-Sánchez 2019, McManus et al. 2019; Trégarot et al. 2020). All figures are expressed in 2015 US dollars.

Coastal Protection from Mangroves

Mangrove-related benefits largely reflect the values provided by the protection they afford coastal populations, infrastructure, and agricultural crops by reducing the risk of economic loss in the event of extreme weather and storms, as well as benefits to fishery enhancement (Narayan et al. 2016; World Bank Group 2016; Losada et al. 2018; Worthington et al. 2020). The value of the mangrove benefits was calculated using statistical regression (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 sustainable uses (medium protection) have a rate of loss 50% lower than the baseline rate of loss; and mangroves under no extractive uses (high protection) have zero loss.

Although we recognize the importance of blue carbon benefits, we did not include possible mangrove blue carbon values as part of the benefits modeled. Despite significant advances, country-specific data on avoided emissions from mangroves at risk of conversion are not currently available at global scales, and further research is needed to expand the inclusion of blue carbon ecosystems in climate mitigation and adaptation accounting frameworks (Hussain et al. 2011; Howard et al. 2017; Worthington et al. 2020; Adame et al. 2021).

Coral Reef Tourism

In addition to hosting more species than any other marine ecosystem (Jänes et al. 2020), coral reefs provide coastal protection and contribute significantly to the coastal tourism economy (Hussain et al. 2011; Spalding et al. 2017; Brander et al. 2020). Creating new MPAs that include coral reefs may contribute to visitor flows by increasing access to high-quality coastal recreational areas (Weiler 2006; Fredman et al. 2007). For example, SCUBA diving is one of the highest value components of tourism-based reef benefits and MPAs are well-known globally for their abundant marine life and other unique recreational features (Spalding et al. 2017).

Industrial and Artisanal Fisheries

For fisheries benefits, we compared each scenario's estimated economic value of all wild-caught fish landed after MPA expansion to the landings value expected in the absence of the new MPAs. The impact of MPA expansion on fish landings can be both positive and negative depending on the target species. MPAs may reduce catch in the immediate post-implementation phase, but this impact can be mitigated over time when greater yields in biomass and landing value increase over the baseline (McCook et al. 2010; Sala et al. 2021).

The estimates of fisheries benefits were derived from the same models used to generate the opportunity costs, and rely on a complex set of biological and economic sub-models to project the future patterns of fish stocks, fishing effort, and fisheries landings and sales from 2020–2100 (see Supplemental Materials). Since the forgone landings value is already calculated as an opportunity cost, we only consider benefits as the positive change, in which the post-expansion landings value exceeds the initial losses as fish stocks recover. We treat all non-positive outcomes as zero net benefits to fisheries.

Findings and Discussion

In a feeding frenzy, humpback whales, gulls and diving birds feast on anchovies schooling near the surface of Monterey Bay. © *Douglas Croft/TNC Photo Contest 2021*

Findings and Discussion

This high-level analysis provides costs and benefits estimates that can be used to inform an ongoing dialogue about marine protection. They are intended to provide a basic reference by which to identify and assess opportunities for a wide array of public, philanthropic, and private finance mechanisms for ocean conservation (Bohorquez et al. 2022). These estimates are not intended to replace those that would emerge from a detailed, participatory, and inclusive process with stakeholders and rightsholders about what to protect, where to protect marine systems, and how to manage them. We summarize and discuss our high-level findings and expand on them in the subsequent sections before making further recommendations.

KEY FINDINGS

- Establishment costs are the lowest cost across all scenarios and for all income groupings. This holds true whether establishment costs are viewed as totals or amortized over time. For countries that need to protect more than 200,000 km^2 to reach the 30% protection goal (the majority of countries in our sample), the lower and upper bound estimates of total establishment costs ranged between US$850,000 and US$2.8 million (2015 constant values) or between US$23,000–$94,000 per year.
- Average annual management costs of increasing protection to 30% protection range from less than US$500 to over US$1 million per km^2, implying total annual management costs per country between US$17 million and US$36 million per year for the focal set of 64 countries of interest. This wide range reflects the income group of the country, potential economies of scale, and the cost of achieving adequacy.
- Opportunity costs, estimated in terms of forgone fishing revenues, make up the largest portion of overall costs. Under most combinations of ocean ecosystem forecasts, fish biomass and revenues may struggle to recover without comprehensive ocean management outside of the 30% MPA network. Scenarios that deploy mixed protection, particularly in the offshore, see reduced fisheries opportunity costs and faster transition to fisheries benefits than in other scenarios. This could suggest that a strategic, mixed protection network (e.g., medium and high levels of area-based management) may be best when fisheries dependencies are high.
- For most countries in our study, costs and benefits are in the same order of magnitude, which provides helpful high-level narratives for governments to justify ambitious policy commitments toward the 30% protection goal, but this does not reflect the critical nuance of how costs and benefits flow and accrue differently across sectors, groups or communities.
- Additional opportunities exist for countries with high-tourism dependencies to expand the benefits delivered from coral and mangrove ecosystems. Our results show that when these countries have more than 200,000 km^2 to protect to achieve the 30% goal, benefits may be up to six times higher by mid-century if effective high protection is established for these ecosystems.

It is important to re-emphasize that this study provides only high-level estimates to inform ocean conservation, and it is not a comprehensive analysis of all the costs and benefits that may flow from ocean conservation. As a study based on predictive global models, this work will not capture local specificity or all costs or benefits related to implementation and management of a 30% protection goal, nor the complexity of fisheries management. Furthermore, there are country-specific data that were not captured here, such as variations in exposure to the risk of extreme climate-related events (Game et al. 2008) or in the strength of governance, enforcement, and surveillance regimes (Giakoumi et al. 2018). Such variations will necessarily affect the estimates of costs and benefits from increased MPA coverage. Despite these caveats, the study remains a reference point for those negotiating and implementing large-scale ocean protection projects, as it provides a starting range of costs and associated benefits.[23] This type of information will be necessary for successful implementation of large-scale ocean protection projects, as it allows for improved planning, design and negotiation of sustainable financing packages for durable conservation.

Given restrictions on the use of the confidential costing dataset for country-level costs, we anonymize and group countries in our focal set for publishing. However, we provide further information in the Supplemental Materials and can provide information on country-specific results to representatives, agencies or organizations working on behalf of those governments for conservation planning purposes, upon request.

23 Country-level data are available for governments seeking to protect their marine ecosystems but not shared explicitly in this aggregated version of the analysis.

A group of soldierfish in Maldives © *Romeo Bodolai/TNC Photo Contest 2022*

ESTABLISHMENT COSTS

To estimate establishment costs, existing models are typically driven by the number of MPAs being established and the time required to plan (Figure 1; see Binet, et al. 2016). For countries that need to protect 200,000 km^2 or less to achieve the 30% goal, total establishment costs on average ranged across income groups between lower bound estimates of US$23,500 and US$640,000 and upper range estimates of US$1 million and US$2.3 million. For countries that need to protect more than 200,000 km^2 to achieve the 30% goal, the lower bound estimates of total establishment costs ranged between US$850,000 and US$1.8 million and upper estimates reached US$2.8 million (2015 constant values). This means establishment costs can fall in a range of between US$800 and US$400,000 per year (over 30 years), depending on the amount required to protect, the location of MPAs, potential economies of scale, and how this cost is financed. From our own experience budgeting for MSP processes around the world, we estimate US$500,000 up to US$1 million per year of planning to ensure that the process is adequately staffed and stakeholders and rightsholders are consulted to shape the MPA plans. We do not consider transitional assistance or compensation schemes in these estimates.

Although these costs are often expended over the planning stage, one can also reflect these costs as annual averages of payments over time so that they can be more easily compared with ongoing management costs. We show these costs amortized over a 30-year period at 5% (high cost) and 0% interest (low cost) respectively. Overall, establishment costs reflect less than 1% of the total annualized costs (i.e., the sum of establishment, management, and opportunity costs).

MANAGEMENT COSTS

Figure 3 compares mean annual management costs across the three scenarios and their inshore and offshore MPA variations (Table 1).

Our findings reinforce that high-protection regimes can have relatively lower management costs, largely due to less surveillance and enforcement requirements (Ban et al. 2011), than medium-protection regimes where sustainable uses (e.g., sustainable fisheries) are allowed inside MPAs (Davis et al. 2015). The "Mixed Protection" scenario, for example, requires overall higher investment in management than those with dominant high-protection coverage (i.e., "High Protection" scenario). This holds true across income groups (Figure 3A) and fisheries- or tourism-dependent countries, where more than 20% of export revenues are generated from those industries (Figure 3B-C). The "High Protection" scenario, which assumes all new protection will be high protection (Table 1), is the most cost-effective to manage across all results. For countries with less than or equal to 200,000 km^2 to protect to achieve the 30% goal (this category includes >90% of the 64 countries), upper-middle income countries (N=14) incur the highest management costs for all scenarios (Figure 3A). This is partially explained by the fact that these countries, on average, have more area to protect than the other income groups (i.e., average area required to achieve 30% protection goal = 74,200 km^2).

For most countries, the average annual management costs were estimated in the tens of millions of dollars (2015 USD) per year or less, but for several countries, particularly those with larger ocean domains or high local expenses, costs were in the hundreds of millions of dollars (2015 USD) per year. For example, in countries with higher income per capita and a longer coastline, management costs could be as high as US$300 million per year or more. We also note that we did not allow for the 30% MPA coverage to form a single large, contiguous area, thus these higher costs also reflect the cost to manage multiple MPAs. However, for the majority of countries in our focal set, the annual management costs per year are in the tens of millions of dollars (2015 USD) (Figure 3).

It is important to note that we avoided the assumption that 30% protection could form a single MPA, since this would represent a potentially unjustified level of extrapolation from the data used in the original studies, and instead used the statistical expectation (based on the data) of the mean size of individual MPAs given the size of the national system.

This photo of a humpback whale tail was taken near the coast of Vancouver Island. © *Jessica Relkoff/TNC Photo Contest 2019*

FIGURE 3. MANAGEMENT COST DISTRIBUTION ACROSS SCENARIOS. *Management cost frequency distribution in US$ millions across "High Protection" (blue), "Mixed Protection" (orange), and "Mixed-High Protection" (green) scenarios for countries with a remaining area to achieve 30% protection target less than or equal to 200,000 km² (left) and more than 200,000 km² (right) represented by: A) By income group; B) High fisheries dependence (fisheries contributing more than 20% of exports revenues); and C) High tourism dependence (tourism contributing more than 20% of exports revenues).*

OPPORTUNITY COSTS

Opportunity costs are represented in Figure 4 as negative values in the graphs because they are losses to certain sectors or groups. Where they turn positive ("Mixed Protection" scenario), it is primarily because fish stock recovery outweighs the losses, or fishing effort adjusts in response to changes in global market conditions and external demand. It is important to note that those experiencing the initial losses and subsequent gains may be from different groups or sectors. Moreover, initial costs are experienced with greater certainty and are experienced by identifiable groups and sectors, whereas future costs and benefits are both less certain and may accrue to different actors, or even new entrants into the fishing economy that have yet to be identified.

The general pattern across all scenarios is that greater opportunity costs are incurred with high-protection allocations ("High Protection" and "Mixed-High Protection" scenarios) than when medium protection is balanced for sustainable fishing. This pattern was consistent across all OEM forecasts (i.e., whether one assumes strong improvements in fisheries management sustainability and more limited climate change impacts in the future, or whether one assumes little improvement in fisheries management and more extensive climate impacts; Table 1). Allowing reduced but sustainable fishing in half of the MPA area ("Mixed Protection" scenario) had the lowest opportunity cost, in terms of forgone fisheries revenues, under all scenarios and was the only configuration to deliver fisheries benefits over time (Figure 4; Waldron et al. in preparation). It is important to note, however, that the impact of an extensive MPA system on the fisheries sector will depend not only on access rules inside MPAs, but also on the trajectory of fisheries management practices across the entire seascape (Brown et al. 2009) and international attempts to keep global warming to two degrees Celsius.

We find that in general, given the varying assumptions of the OEMs, when high protection is a part of the strategy ("High Protection" and "Mixed-High Protection" scenarios), overall opportunity costs for fisheries are higher, since fish stocks may struggle to recover beyond current levels without additional comprehensive ocean management. Despite this, high protection MPAs are a critical component of fisheries recovery and are fundamental to delivering fisheries sustainability (Metcalfe et al. 2015; Sala et al. 2021) and benefits beyond fisheries profits. However, irrespective of the amount left to achieve the 30% protection goal, those countries with the lowest income classes experience the greatest recovery and reduction in loss of fisheries revenue over time.

Fisheries revenue losses also diminish over time as fish stocks recover in countries with high dependence on fisheries and tourism. In these examples, fisheries and tourism dependence reflect the countries' income status, since most of these economies are fairly small and lower-to-middle income (see Supplemental Materials).

Fishermen unload their tuna catch at the Vieux Fort fish market in Saint Lucia. © *Tim Calver*

OPPORTUNITY COSTS

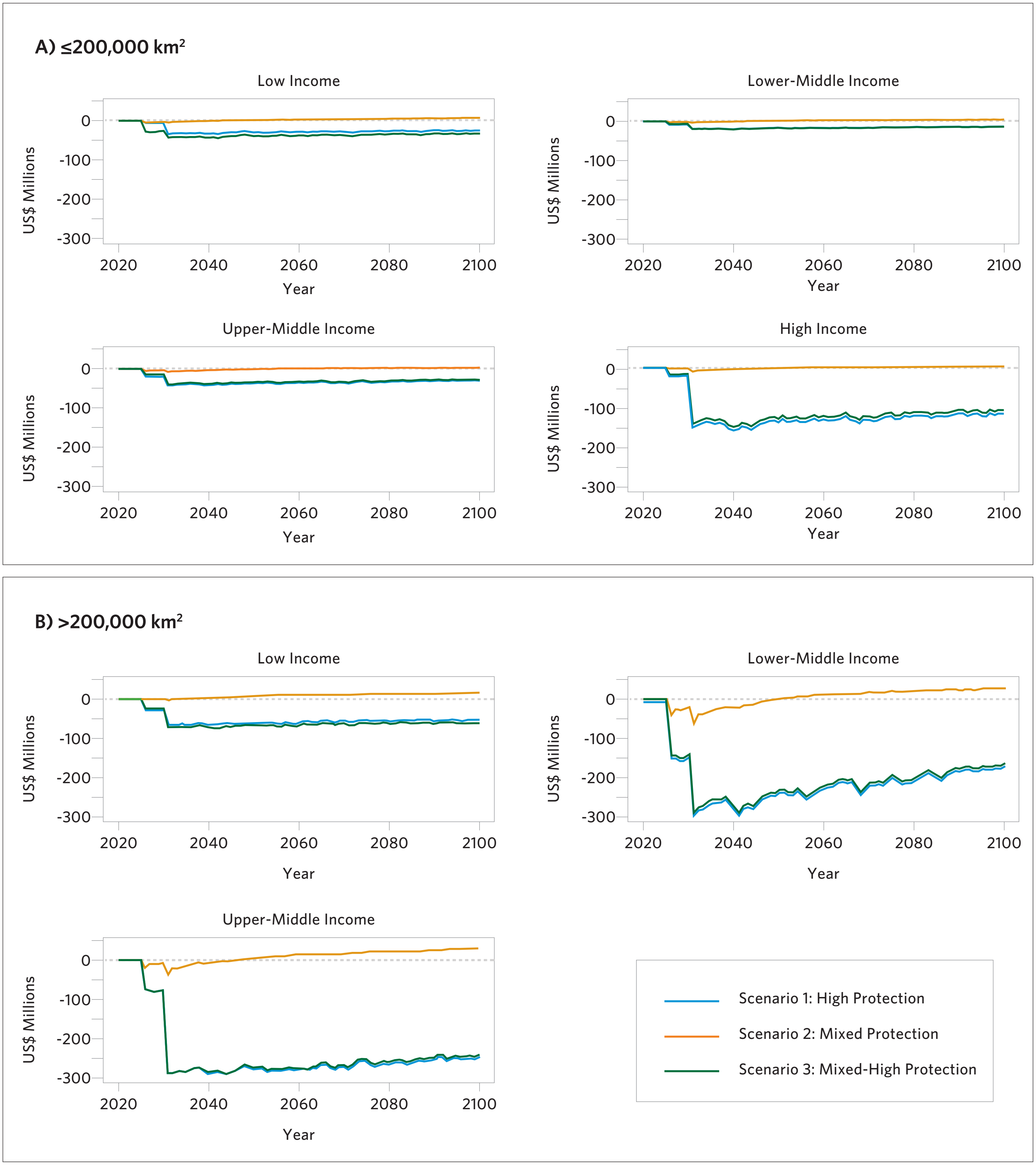


FIGURE 4: OPPORTUNITY COST OVER TIME FOR THE DIFFERENT SCENARIOS (SSP 3 + RCP 7.0). *Opportunity cost in US$ millions over time for the different scenarios "High Protection" (blue), "Mixed Protection" (orange), and "Mixed-High Protection" (green) for countries across different income groups using mid-range climate forcing (SSP 3 + RCP 7.0) with a remaining area to achieve 30% protection target: A) Less than or equal to 200,000 km² and B) More than 200,000 km². Opportunity cost is represented as negative values (below dotted line representing 0 value) as there are fish stocks losses to certain sectors or groups, and positive values (above dotted line representing 0 value) as fish stock outweighs the losses for certain sectors or groups.*

Because Small-Scale Fisheries (SSFs) are an especially vulnerable subset of total fisheries, we analyzed patterns in SSF-specific opportunity costs for countries highly dependent on fisheries (Waldron et al. in preparation). In the “High Protection” scenario, a small majority of focal countries showed an increase in SSFs catches, remaining steady over time. A likely explanation for increased SSFs catches is that industrial fishers were being kept out of some newly protected waters (Jumin et al. 2018). In several countries, MPA expansion was projected to drive large percentage losses in SSFs revenues — typically exceeding 25%. Such projections arose when modeled high-biodiversity areas had significant overlap with important SSFs fishing grounds, and thus, the “High Protection” scenario, which conservatively assumes 30% in high protection, had a disproportionate impact on SSFs in the inshore areas. However, we note that in many places, where temporary and seasonal closures are part of traditional fisheries management approaches, communities will regularly transition to alternate revenues during these periods (e.g., seaweed gleaning). Learning from fishing communities and collaborating with SSFs when designing coastal and marine conservation and climate adaptation strategies is essential.

Using a mix of high and medium protection (“Mixed Protection” scenario) greatly reduces the opportunity costs to SSFs and over time increases SSFs catch values in most countries by between 5% and 25%. Even so, some countries still had negative SSFs outcomes, suggesting a particularly strong overlap between smaller-scale fishing areas and modeled high-value biodiversity areas in those places.

ECONOMIC BENEFITS FROM FISHERIES, COASTAL PROTECTION, AND TOURISM

The economic benefits of MPA expansion to 30% were often considerable and increased over time from 2030 to 2060. These benefits include (1) fisheries recovery over time (e.g., the trends from Figure 5), (2) protection from storms, and (3) tourism revenues. For example, when summed across all 64 countries using the mid-range estimate, the total benefit was US$4.4 billion to US$6.3 billion per year in 2030, rising to US$9.4 billion to potentially US$14.7 billion per year in 2060. Pre-Covid-19 projections estimated the global ocean economy (all sectors and industries) to be valued to US$3 trillion by 2030 (Sumaila et al. 2021); our results are in line with this rapid growth in the blue economy but focus on the role MPAs can play in this trajectory. However, because we limited our calculation to only a few well-established economic benefits derived from MPAs, these values necessarily will be lower bounds of the full range value of benefits that accrue to countries from greater marine protection.

When reviewing benefits, we caution against comparing net costs and benefits to each other. The costs to establish and manage MPAs typically fall on governments, opportunity costs typically fall on sectors, groups, and communities; and the recipients of quantifiable benefits are likely to be different than those bearing the costs. Modeling of these refined distributional flows is beyond the scope and aim of this rapid analysis, but it is critical to planning and adaptive management decisions where justice, equity, and inclusion need to be considered.

“High Protection” and “Mixed-High Protection” scenarios, which offer majority high protection to inshore environments such as mangroves and reefs, consistently deliver larger benefits than the “Mixed Protection” scenario (Figure 5). Low-income countries that need to protect up to 200,000 km^2 to reach the the 30% goal stand to gain the most benefits from these protection scenarios over time (see Figure 5A). The one exception we observed was for lower-middle income countries with more than 200,000 km^2 to protect to achieve the 30% goal. For these countries, a protection approach with a mix of high and medium protection (“Mixed Protection” scenario) delivers the largest benefit range (Figure 5B).

Repairing fishing nets at a temporary fishing camp on the south coast of Samana Bay in the Dominican Republic © *Mark Godfrey/The Nature Conservancy*

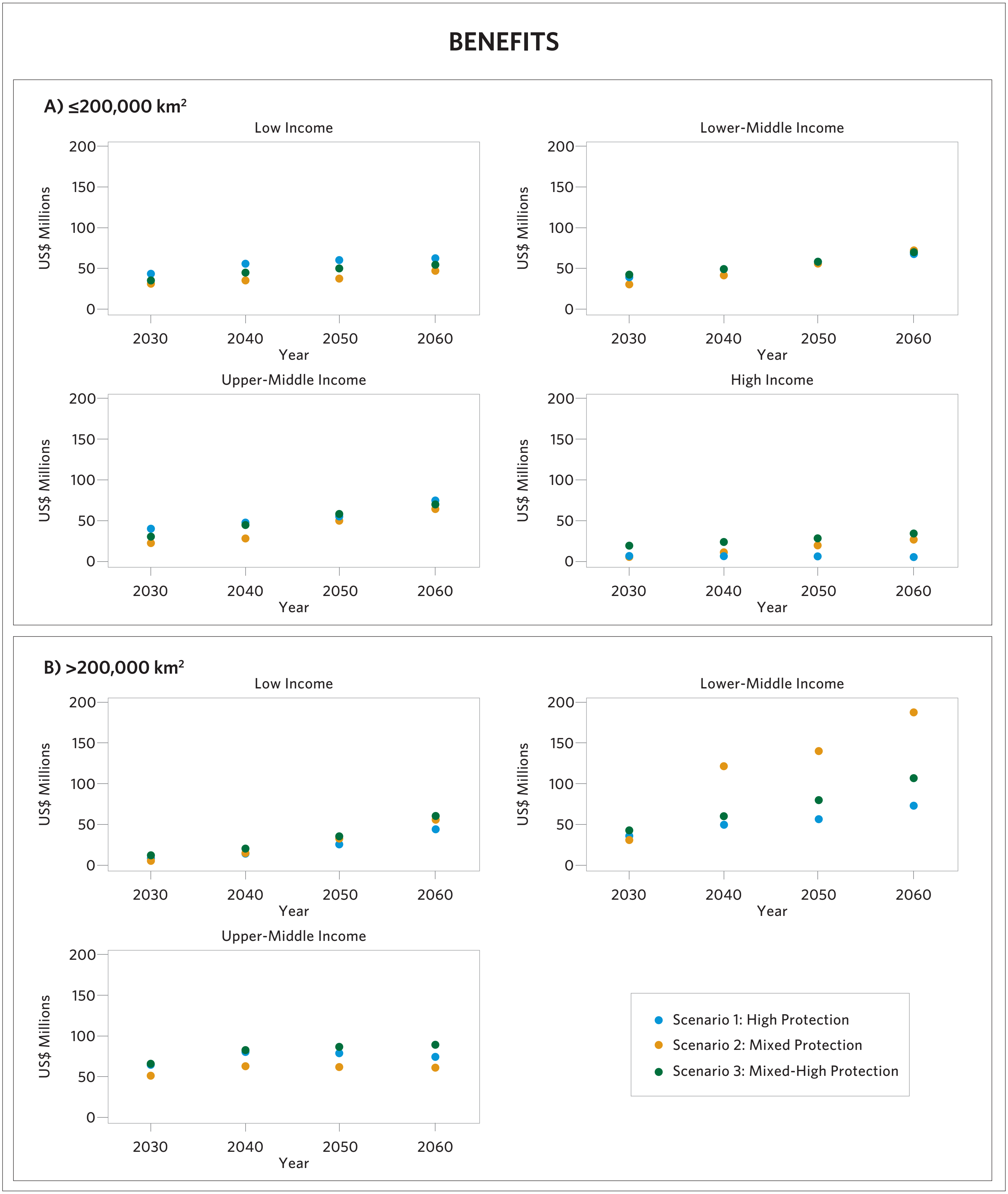


FIGURE 5: BENEFITS OVER TIME FOR THE DIFFERENT SCENARIOS *Benefits in US$ millions over time (2030, 2040, 2050 and 2060) for the different scenarios "High Protection" (blue), "Mixed Protection" (orange), and "Mixed-High Protection" (green) for countries across different income groups, with the remaining area to achieve 30% protection target: A) Less than or equal to 200,000 km² and B) More than 200,000 km². Benefits include fisheries, coastal protection and tourism.*

At the country level, the size of the benefits varies, but more importantly, so does the magnitude by which we likely underestimate the benefits. We also see that the benefits estimates are more tightly clustered in all but the high-income countries where we have the greatest dispersion of benefit estimates by scenario at each point in time. This dispersion most likely reflects the differences in size of the fisheries and tourism sectors.

For our subset of 64 countries, the most obvious cross-country variation is that no benefits can be calculated for countries that have no mangroves, no reefs and/or no overfished areas. Holding all other factors constant, any country with only one or two of those benefits will also have lower estimated economic benefits than a country with all three benefits in this analysis. Therefore, the most informative set of countries to focus on during this analysis are those 31 countries that have all three sources of expected benefits measured from mangroves, reefs, and fisheries. We note that although the following findings are most relevant to this subset, the benefits of MPAs in other contexts and ecological systems are equally relevant to consider and should be prioritized for further research.

Within the subset of 31 countries that have all three sources of expected benefits, annual economic benefits (as measured in 2050) often exceed annual management costs by up to 10 times. However, given the range of protection and extent of these systems across the 31 countries, mangroves, reef tourism, and overfishing are simply less prominent in some countries' economies than others. For example, in a country with limited existing tourism, it is harder for benefits to accrue than for countries where tourism already drives the economy. Similarly, for a country in which reefs and mangroves are not represented in their MPA system, benefits from their protection are likely to be low (while costs of a large MPA system are high).

For countries with high tourism dependence, high protection in the inshore presents an important economic opportunity, as our results show expanded growth in benefits over time from protection of corals and mangroves (Supplemental Materials). If these countries receive appropriate capacity-building assistance in order to capitalize on the economic value of their MPAs, then the benefits could grow three to six times by mid-century. Certain countries lack the ability to capture a sizable benefit because they lack a specific development capacity, such as tourism infrastructure and services, rather than as a result of their geographic characteristics. Developing this capacity could potentially enable these countries to increase the benefits derived from any future MPA expansion.

Another important case in which MPA expansion seems to bring no additional benefits occurs when a country has already protected approximately 30% of its Exclusive Economic Zone (EEZ). In our sample, only two countries have achieved this objective (Sala et al. 2021), but they deliver fewer benefits because they have not fully implemented or legally enforced 30% of their EEZ. The converse of this situation again illustrates an important principle: countries that currently protect very little of their marine ecosystem would likely receive the largest relative benefits from expanding to 30% protection. It is important to note that when there is no expansion needed to achieve the 30% protection goal, this does not mean that a country's MPAs provide no economic benefits, but rather, that the benefits have occurred prior to 2020 (and will likely continue into the future). It is worth underscoring, however, that very few countries have adequately protected their existing MPAs, and most remain underfunded and ineffectively managed (Gill et al. 2017; Sala et al. 2018).

Conclusions

Mangroves in Alligator Creek, Cat Island, Bahamas © *Shane Gross*

Conclusions

This study aims to provide high-level estimates of the potential costs and benefits of protecting and improving the management of up to 30% of a country's EEZ to maintain vital economic, social, and ecological benefits for nature and people. These estimates are intended to support decisions on how these costs might be covered and how resources can be mobilized domestically or from other sources to achieve global ocean conservation objectives.

THE NEED FOR STANDARDIZED COSTING FRAMEWORKS

The last 15 years have seen tremendous growth in area-based conservation. Reviews, surveys and modeling efforts to better estimate the costs and benefits of MPAs and OECMs are improving over time but efforts remain piecemeal (regional or subnational), uncoordinated, and even behind paywalls (e.g., academic publishing; Iacona et al. 2018). The analysis presented here, and the enormous challenges encountered in finding comparable data, harmonizing costing frameworks and exploring the management and establishment costs of MPAs, underscore the urgent need to create a common framework and template for costing marine protection. Pioneering work by the Biodiversity Finance Initiative (BIOFIN), UNDP, and other entities (see Bodin et al. 2022) shows that such an aspiration is possible. Developing a repository of open-access costing information, using standardized templates and frameworks, to enable governments and subnational entities to calculate the costs of different types of marine protection, should be considered a priority to deliver the 30x30 agenda and the GBF over the next decade. Ideally, such a repository would be hosted by a centralized agency to overcome the challenge of collating and curating fragmented and highly dispersed information. Costing and accounting data should be required by donor governments, foundations, and multilaterals supporting MSP for all recipients of financial support for area-based management. The collaborative project The Economics of Ecosystem Restoration (TEER) could be a useful model to draw from for standardized templates, convening global information and developing a dynamic, global database on the costs and benefits of conservation actions for ocean conservation and area-based management.

THE CENTRAL ROLE OF INCLUSIVE MARINE SPATIAL PLANNING (MSP) AND COMMUNITY ENGAGEMENT

Given the size of the opportunity costs estimated here, we reiterate that choices of where to protect and improve management of MPAs, and how to protect them, must emerge from a rights-based, participatory, and inclusive spatial planning process that involves stakeholders and rightsholders. The costs of large-scale conservation need to be estimated, understood, and included in the policy development process to ensure that burdens are shared equitably, and that the significant benefits that society as a whole derives from protecting biodiversity are equitably distributed (Campbell and Gray 2019; Dudley and Stolton 2022). Ensuring inclusive planning and consultation improves stakeholder buy-in for MPA networks, which may ultimately reduce management costs over time, if compliance is effective (Giakoumi et al. 2018).

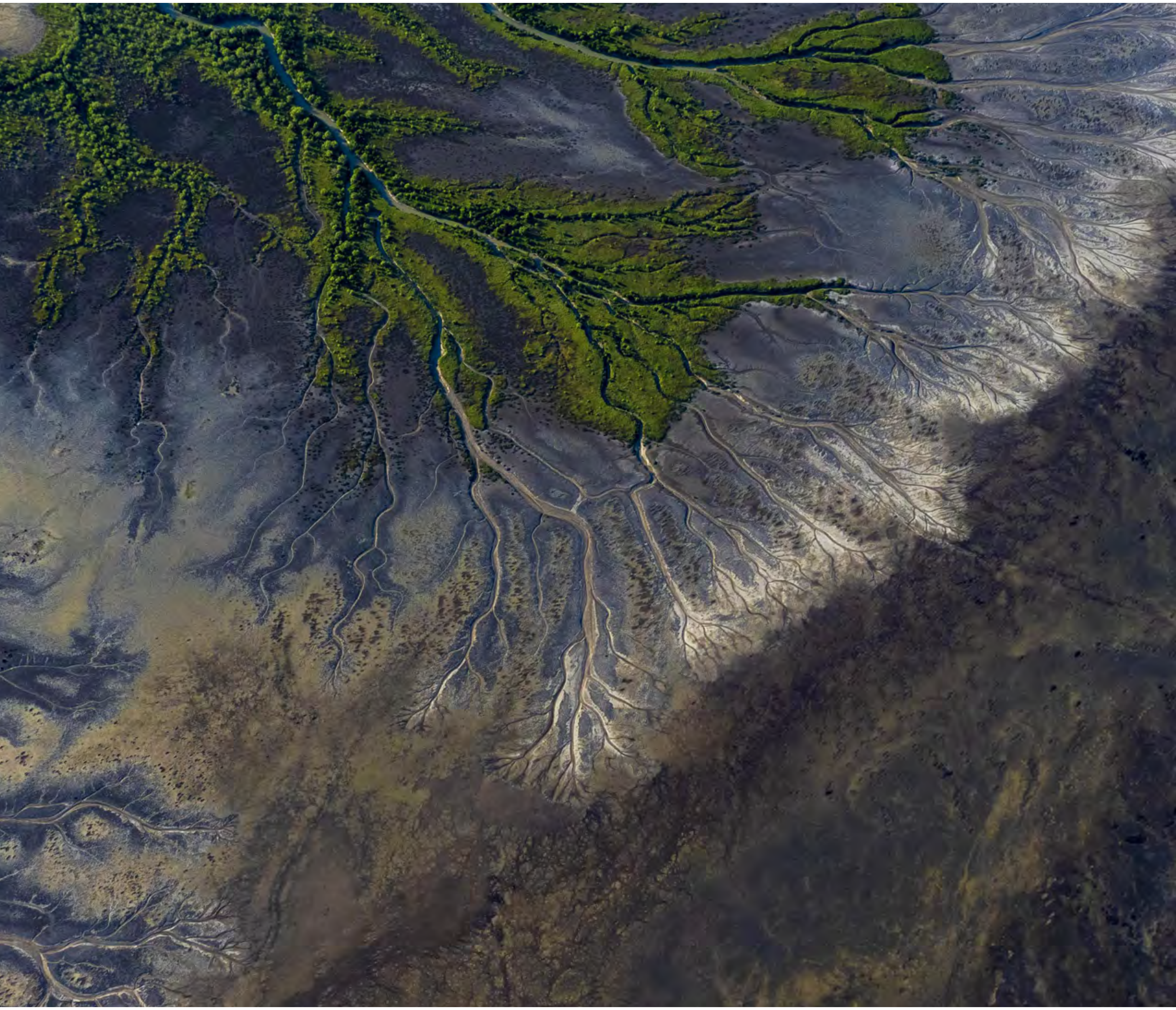
MOBILIZING RESOURCES IN THE CBD

The results from this study suggest that the establishment, management, and opportunity costs from increased marine protection are on the same order of magnitude as the estimated benefits in many countries. Since the costs and benefits are not equally distributed on a global, national, or subnational level, resource mobilization will likely be required to support both direct implementation and any livelihoods or sectoral transitional assistance alongside the development of new and more sustainable industries. The choice of how to mobilize these resources, whether, for example, through debt conversion, Official Development Assistance (ODA), issuing or acquiring new sovereign debt, reprioritizing existing budget lines (e.g., addressing harmful subsidies), raising taxes, or levying fees and fines must lie with each country. Yet, a global commitment to protecting 30% of our oceans by 2030 requires global collaboration and responsibilities to secure adequate funding to achieve these commitments. This necessarily means that some countries will have to help with that transition when the costs fall disproportionately on poorer nations.

Finally, although increasing marine protection is important for protecting the health of the oceans, protected areas alone will not be enough. Area-based conservation (e.g., MPAs and OECMs) presents one mechanism to deliver a sustainable blue economy and must be considered as a component of comprehensive marine spatial planning for the global ocean. The different climate forcing scenarios in this study suggest that we may have significantly different outcomes in the face of increasing climate change impacts (Brown et al. 2009). While not assessed directly in this study, area-based conservation alone is not enough to deliver and maintain benefits if other threats like acidification, pollution, and land-based threats are not addressed. These findings are in line with the latest Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) report setting out the main pressures on the ocean and the conclusion that all of these pressures have to be tackled together to ensure the long-term health of the oceans (IPBES 2019).

HOW WE HOPE THIS WORK WILL BE USED

This study provides an important approach for the global conservation community as we collectively take on delivering the GBF and supporting countries that are committing to the 30x30 goal for national waters. Information on what it might cost to protect 30% of a country's ocean remains scarce and can be expensive and time consuming to obtain. We aim to provide a plausible range of costs and benefits to allow policy makers, funders, and conservation practitioners to begin discussions on the magnitude of funding required and the opportunities for a broad suite of benefits to be delivered from ambitious area-based conservation commitments. As such, we recommend that this study is used in the initial stages of the marine conservation policy development process. We underscore that these initial insights need to be supplemented with nationally specific work to localize the findings from the global model utilized in this study.



During the wet season, the Gulf of Carpentaria in tropical north Queensland holds a myriad of winding rivers, estuaries, creeks and streams that create one of nature's intricate vivid landscapes. Lush green mangroves line the mud flats accentuated by the tidal waters and months of rain filling the artesian basin. © *Scott Portelli/TNC Photo Contest 2021*

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A huge school of yellowstripe scads in tight formation in the waters of Dampier Strait off the Raja Ampat Islands of Indonesia © *Jeff Yonover*

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Acronyms

Aerial view of the Nahtik Marine Protected Area adjacent to the Enipein Mangrove Forest Reserve, Pohnpei, Micronesia © *Nick Hall*

Acronyms

AIS	Automatic Identification Systems
BIOFIN	Biodiversity Finance Initiative
BOATS	Bioeconomic Marine Trophic Size-Spectrum
CBD	Convention on Biological Diversity
EEZ	Exclusive Economic Zone
GBF	Global Biodiversity Framework
GDP	Gross Domestic Product
IPCC	Intergovernmental Panel on Climate Change
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
LMMA	Locally Managed Marine Area
MPA	Marine Protected Area
MSP	Marine Spatial Planning
NGO	Non-Governmental Organization
ODA	Official Development Assistance
OEM	Ocean Ecosystem Model
OECMS	Other Effective Area-based Conservation Measures
RCPs	Representative Concentration Pathways
REM	Remote Electronic Monitoring
SIDS	Small Island Developing States
SSFs	Small Scale Fisheries
SSPs	Shared Socioeconomic Pathways
TEER	The Economics of Ecosystem Restoration
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
WDPA	World Database on Protected Areas

The Nature Conservancy