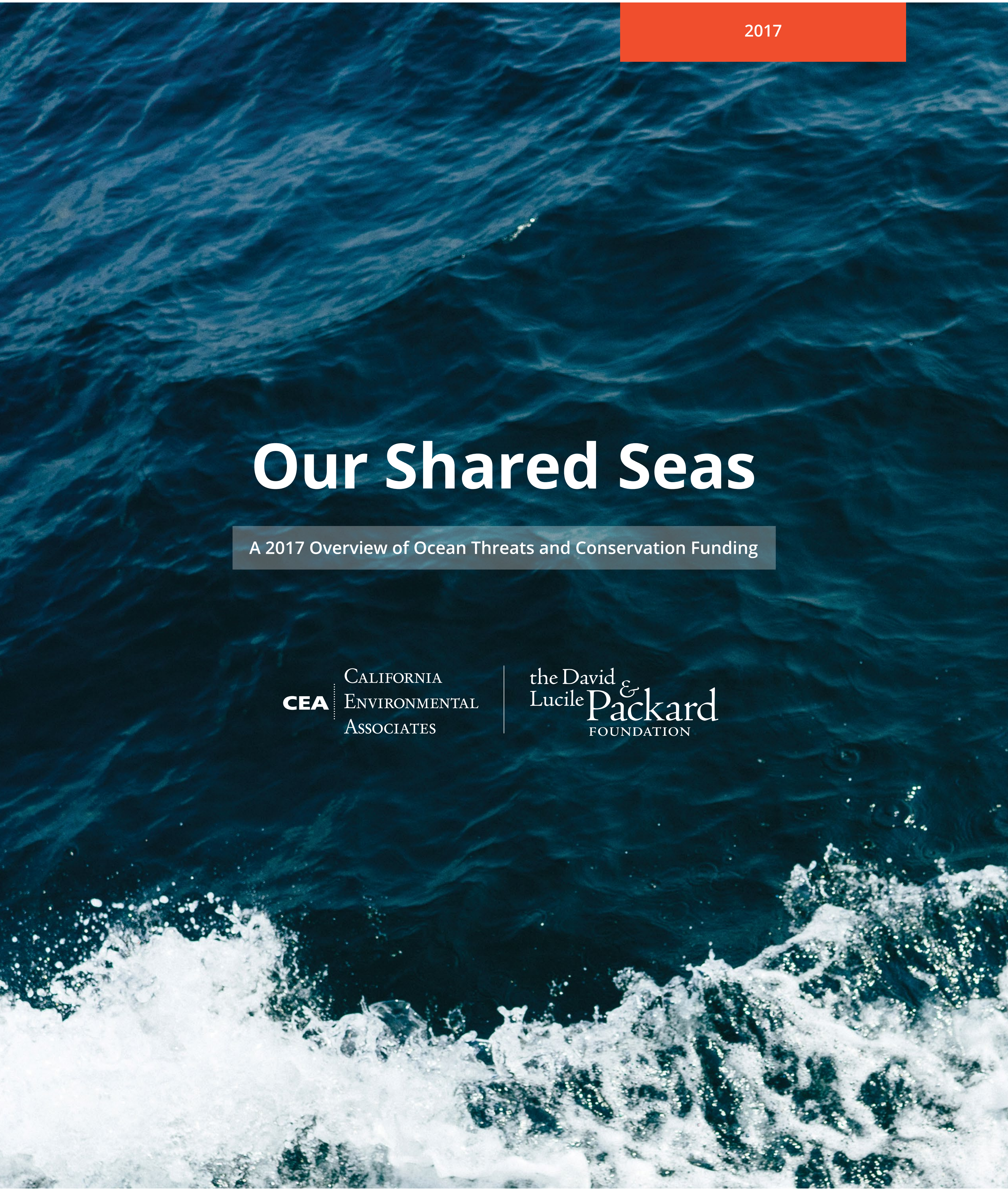


2017

Our Shared Seas

A 2017 Overview of Ocean Threats and Conservation Funding

CEA California Environmental Associates

the David & Lucile Packard Foundation

the David & Lucile Packard FOUNDATION

CEA California Environmental Associates

California Environmental Associates. 2017.
"Our Shared Seas: A 2017 Overview of Ocean Threats and Conservation Funding."

Prepared with the support of the David and Lucile Packard Foundation.
Report and supplementary materials available at: www.packard.org/oursharedseas.

Design: Weirdesign.com


Photo: © Matt Kieffer

List of Acronyms

AIS	Automatic Identification System
ASF	animal source foods
B_{MSY}	the biomass that enables a fish stock to deliver the maximum sustainable yield
CBD	Convention on Biological Diversity
CEC	contaminant of emerging concern
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CO_2	Carbon dioxide
CRS	Creditor Reporting System
CTF	Conservation Trust Fund
DDT	Dichlorodiphenyltrichloroethane
EEZ	exclusive economic zone
FAO	Food and Agriculture Organization of the United Nations
FIP	fishery improvement project
GEF	Global Environment Facility
GHG	greenhouse gas
IBRD	International Bank for Reconstruction and Development
IDA	International Development Association
IFAD	International Fund for Agricultural Development
IMFC	Indonesia Marine Funders Collaborative
IPCC	Intergovernmental Panel on Climate Change
IUU	illegal, unreported, or unregulated
MBARI	Monterey Bay Aquarium Research Institute
MDB	multilateral development bank
MMI	Marine Microbiology Initiative
MMT	million metric tons
MPA	marine protected area
NGO	nongovernmental organization
ODA	official development assistance
OECD	The Organization for Economic Co-operation and Development
PCB	polychlorinated biphenyl
POP	persistent organic pollutant
PPM	Parts per million
RCP	Representative Concentration Pathway
SST	Sea surface temperature
UNFCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
WDPA	World Database on Protected Areas
WWF	World Wildlife Fund

Table of Contents

Meg Caldwell
Deputy Director, Oceans
Conservation and Science
The David and Lucile Packard Foundation

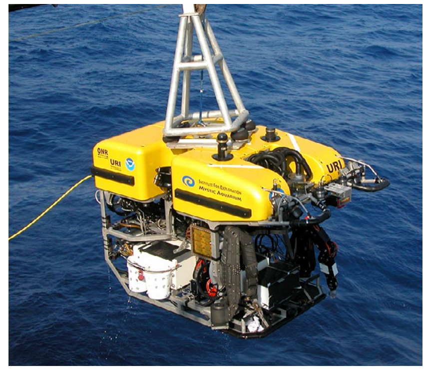
The global ocean is at a crossroads with pressure coming from many sides.

Climate change, overfishing, pollution, shipping, coastal development: there is no shortage of threats facing the marine environment. Recently, an increasing number of philanthropists and aid agencies have risen to the challenge to support solutions that are within reach.

Given the urgency, how can funders and advocates understand the most pressing threats and promising solutions and therefore prioritize where to make an impact? *Our Shared Seas: A 2017 Overview of Ocean Threats and Conservation Funding* was commissioned by The David and Lucile Packard Foundation to provide a guide to the primary ocean threats, trends, and solutions to help funders, advocates and governments make better, faster, and more informed decisions.

The message that emerges from this synthesis is clear: when managed well, ocean resources have the potential to simultaneously support thriving ecosystems, sustainable development, and increased fishing profits. But human impacts are swiftly pushing the ocean to its brink.

There are many issues of interest in this guide. For our foundation, three topics in particular strike us as essential for the future health of our ocean: tackling overfishing caused by illegal, unregulated and unreported activities; mitigating and addressing the effects of climate change on the ocean; and improving our scientific capacity to understand and manage all of these compounding pressures.



Illegal, Unregulated and Unreported (IUU) fishing: Recent analysis shows that IUU fishing remains a "dark side" of global fisheries and may be as large as much as 53 percent of officially reported catch. We know how to address this challenge. Solutions that address IUU fishing are especially compelling because they are exactly what we need for responsible and evidence-based marine resource management anyway. Whether it is mustering the political will to enforce long-established international labor standards, better counting and reporting what and where fish are caught so that we know how to sustainably manage fisheries, or enforcing the protections and fisheries management measures—these are some of the essential building blocks of tackling illegal fishing and achieving ocean stewardship.

Climate change: The severity of consequences from climate change on the ocean creates a new sense of urgency for mitigating carbon dioxide emissions and reducing other pressures on the marine environment. The ocean has been a critical barricade against global warming, trapping and absorbing approximately 93 percent of the excess heat produced by greenhouse gas emissions since the 1970s. As a result, the ocean is getting warmer, increasingly acidic, and less oxygenated; these changing conditions are already impacting biodiversity and human security, especially across tropical developing countries. Slowing the accumulation of greenhouse gasses in our atmosphere is critical for the future of the marine environment and its role in buffering our planet from climate change.

Integrated science: This guide also highlights the glaring gaps that persist in our understanding of most marine environmental issues. Our foundation strongly supports more active investigation into these issues, and the better integration and coordination of those working on oceans. Our collective ability to rapidly diagnose and respond to the unforeseen effects of climate change and to understand the synergistic effects of pollution, habitat loss, and other pressures is essential.

An element of the guide that we are particularly excited to share is a first-of-its-kind analysis comparing ocean funding from the philanthropic and development aid communities. Our hope is that this information, also captured in new tools such as the Foundation Center's "FundingtheOcean.org" portal, will provide our partners with a more complete picture to encourage dialogue and inspire action.

The Packard Foundation is aiming to release an update to this guide every couple of years.

We welcome feedback on how it could be improved at oursharedseas@ceaconsulting.com.





Executive Summary

Scope and structure

The purpose of this guide is to synthesize recent trends and emerging research on the marine environment in a plain-language compilation as an information resource for ocean conservation funders and practitioners.

Our Shared Seas is divided into five sections, covering issues related to the state of the ocean and marine conservation work. Each section features a summary of available data, supplemented by visualizations and interpretation of that data. Alongside the data, the guide includes brief perspective pieces with experts commenting on critical issues, trends, or where they believe funders, governments, or NGOs would benefit from further focus.

The issue areas addressed in the guide are as follows:

- **Trends in philanthropic and development aid funding**

  Compiling recent data, this chapter provides an overview of grantmaking, philanthropic funding trends, analysis of development aid funding, and brief findings from a perspective survey of practitioners in the field.

- **The state of fisheries and aquaculture**

  This chapter reviews wild capture landings in recent decades, global stock status, findings from recent fisheries management studies, and production trends and projected growth of the aquaculture sector.

- **The impacts of climate change on the marine environment**

  This chapter examines climate-induced environmental changes in the ocean, key marine ecosystems at risk, projected impacts of climate change on fisheries production and management, and future implications for the ocean based on the current global climate agreement.

- **Land-based and industrial stressors on ocean health**

  Addressing pressures beyond fisheries and climate change, this chapter details the cumulative human impacts on the ocean, exploring our current understanding of stressors from coastal habitat conversion, global shipping, and pollution from a variety of sources (oil and gas, chemical compounds, and plastics).

- **A progress report on marine protected area coverage**

  This chapter provides a closer look at recent trends in the designation of marine protected areas, progress towards the global coverage target, and level of protection by ocean basin.

Findings

While no attempt is made to provide an overarching assessment of the status of the marine environment, the aggregate trends summarized in this report are clearly concerning. The human footprint on the ocean is expanding in nearly every sector: coastal development, shipping, fisheries, and pollution. Often, these effects are cumulative (e.g., coastal habitat loss), are difficult to document (e.g., pollutants), and interact with each other in underappreciated ways.

On top of these stressors, the widespread effects of climate change on the marine environment are now beginning to be felt, sometimes acutely, with massive uncertainty about what the future holds. With this backdrop of global development, philanthropy has made critical progress in several areas, including establishing large protected areas and improving fisheries management, but time is not on our side. We will likely reach a point, within the order of a few decades, at which options for addressing these challenges will become more limited, less effective, and substantially costlier. Actions taken now to stabilize marine ecosystems and mitigate the impacts of climate change and other stressors will yield significant dividends as this window of opportunity narrows.

Top-level findings from the respective chapters of the guide are presented below.

- ***Philanthropic and development aid grantmaking for marine conservation have been roughly comparable in size in recent years, though they have targeted different parts of the world.*** **During 2015, roughly US $800 million in grant funding was directed toward ocean conservation. Half of those funds originated from foundations, primarily in the United States, and half of those funds came in the form of official development assistance (ODA) grants from bilateral and multilateral aid agencies.**[i] A clear geographic and topical divide persists between the two sources. Philanthropy has invested heavily in fisheries and protected area work, with a geographic emphasis in North America, followed by Europe and the Coral Triangle, as well as in cross-cutting science and market priorities. ODA funding is primarily directed toward Africa and parts of Asia, with an emphasis on poverty alleviation and economic development in low- and middle-income countries.
- ***Most fisheries are fully fished or overfished today, while illegal, unreported, or unregulated (IUU) fishing looms as a "dark side" of global fisheries.*** A majority of fisheries (over 80 percent of assessed stocks) are fully fished or overfished today, though rebuilding of depleted stocks has begun in some regions and has yielded significant benefits. **Recent analysis shows that IUU fishing may account for as much as 53 percent of reported catch.**[ii,1] Global trends in fisheries and aquaculture are well documented. Total fisheries landings have plateaued or started to decline, despite increasing fishing effort, while aquaculture production continues to expand in tandem with consumer seafood demand. Analysts agree that few underexploited stocks remain and that there are substantial economic and biodiversity upsides to rebuilding fisheries. A recently published governance index provides more detail on which countries have made progress in implementing responsible fisheries management. Among fisheries, IUU landings are an increasingly recognized problem, not only for stock health but also for human rights and national security.

i. Government funding and individual charitable donations are not included in this total.

ii. While an earlier overview study estimated that about 20 percent of global catch is caught illegally, a more rec country-by-country analysis showed that IUU catches may be as high as 53 percent of reported catch. This latter compilation included not just illegal but also unreported recreational, artisanal, and unintended by-catch.

- ***The fundamental chemistry of the ocean is changing at a rate that is unprecedented in human history.*** Climate change-related impacts are confounding fisheries management systems as stocks are shifting; management strategies are losing their predictive capacity and becoming less effective; and conditions for using illegal fishing methods are enhanced. The geographic and demographic impacts of climate change are uneven: those who are most vulnerable include poor populations in tropical developing countries (e.g., the Indo-Pacific and West Africa), given their dependence on fish for food and livelihoods. **An estimated 30-60 percent of the world's corals have disappeared; at the current rate of temperature rise, 90 percent of coral reefs will disappear by 2050.** Coral reef support fish stocks that provide food for one billion people, while an estimated 30 million small-scale fishers depend on coral reefs for their livelihoods. A new initiative seeks to scientifically identify 50 coral reefs that are least vulnerable to climate change and have the greatest potential to repopulate other reefs. Meeting the Paris Agreement, which allows warming by no more than 1.5 degrees Celsius, will be critical for mitigating the most damaging impacts of climate change.

- ***No area of the ocean is completely untouched by human activity. Globally, the greatest threats to the ocean are climate change, commercial fishing, coastal habitat destruction, and pollution.*** Apart from fisheries and climate, marine ecosystems are affected by an array of pressures from industrial and land-based activities. What we do not know about the extent of these pressures is remarkable. Habitat loss to development is cumulative, with roughly a third of coastal wetlands gone. Shoreline hardening, coastal reclamation and sea-level rise are exacerbating that trend. Shipping has more than quadrupled since 1992, with new routes soon to open in the Arctic. And the aggregate effect of pollution on the marine environment is presumed to be worsening. While persistent organic pollutants (POPs) and oil tanker accidents appear to be on the decline, the more insidious stresses of eutrophication, marine debris, plastics, synthetic microfibers, and contaminants of emerging concern are rapidly growing with unknown impacts for marine wildlife and food webs. **Plastic debris accounts for the largest portion of marine litter in the ocean by volume, with an estimated 8 million tonnes of plastic waste entering the marine environment annually from land-based sources.**

- ***The expansion of large-scale protected areas in relatively remote parts of the ocean is a major accomplishment of the last decade, though a significant gap in the global coverage target remains.*** **Despite notable commitments in recent years, the current level of protection is less than halfway towards the Aichi Target 11 of conserving 10 percent of the global ocean by 2020.** The percentage of the global ocean currently in an MPA is 3 percent. Simply implementing the proposed or officially announced MPAs would increase the level of protection to nearly 6 percent of the ocean. Waters from the Ross Sea to the Exclusive Economic Zone of Palau have been designated as massive new MPAs, but opportunities for major new declarations may be declining. There are also calls to better address the ecological connectivity and representation of protected areas, a sub-component of the Aichi Target 11 for which the current global MPA network falls short. Current priorities for the field include building management capacity and long-term financing for MPAs, such as through conservation trust funds, given the lack of public resources currently committed.

About the author

This analysis was commissioned by the **David and Lucile Packard Foundation** and prepared by **California Environmental Associates (CEA)**. CEA takes accountability for any errors or omissions in this compendium, and CEA welcomes constructive feedback from readers by email (**oursharedseas@ceaconsulting.com**).

Marine conservation funding

Ocean-related philanthropic and development aid funding

Private foundations and development aid organizations (which comprises both bilateral and multilateral donors) provide substantial funding for ocean-related issues throughout the world. This report compiles recent data to explore trends from the two sectors, including the level of grantmaking in recent years, key donors, distribution of giving across issue area, and top recipient countries. The structure of this chapter is as follows: a) an overview of foundation and development aid grantmaking, b) a review of philanthropic funding trends, c) a review of official development assistance (ODA[i]) funding trends, and d) brief findings from a perspective survey of practitioners of the field.

A. Comparison of philanthropic and development aid grantmaking

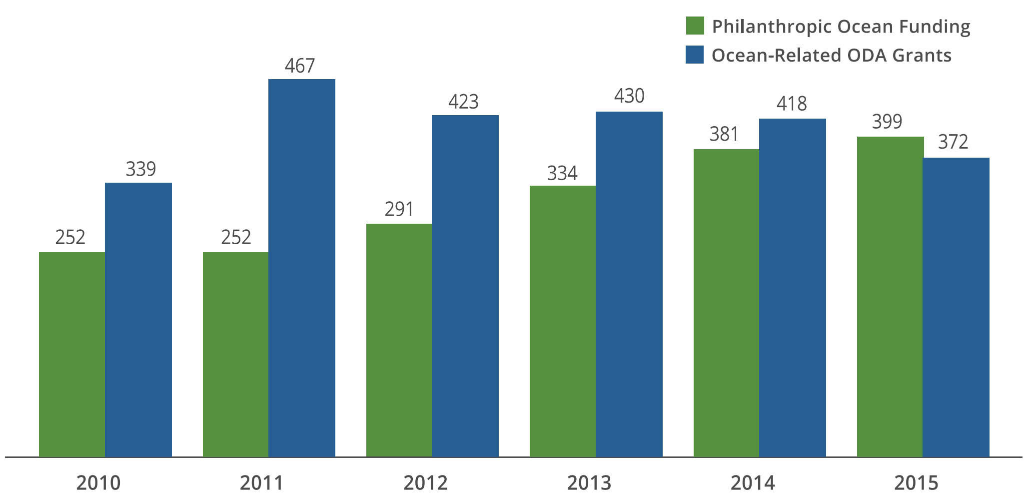
Relative size of philanthropic and development aid sectors

Between 2010 and 2015, the philanthropic sector contributed an estimated US $1.9 billion to ocean-related issues, while ocean-related ODA amounted to approximately US $2.4 billion in grants (Figure 1), for a total of US $4.3 billion, or over US $700 million per year.

These numbers represent a subset of total giving. The philanthropic numbers do not include charitable donations by individuals, and are likely to miss donations from many foundations outside of the United States.

ODA is an indicator of international aid flow aimed at development. While it includes both grants and loans, the data shown below refer only to grants to enable an analogous comparison with philanthropic funding. As such, infrastructure-related grants and all loans are excluded from the amounts reported below.

Total Ocean-Related Grants from Philanthropic and ODA, in USD Millions | FIG. 1



Note: Foundations that did not provide data for 2015 are assumed to have made the same dollar amount of ocean-related grants in 2015 as they did in 2014. One-year commitment amounts greater than US $30 million dollars have been split over multiple years. Moore Foundation grants are factored in as disbursement amounts rather than commitment amounts.

[i] According to the OECD, official development assistance is defined as: "Flows of official financing administered with the promotion of the economic development and welfare of developing countries as the main objective, and which are concessional in character with a grant element of at least 25 percent. By convention, ODA flows comprise contributions of donor government agencies, at all levels, to developing countries ('bilateral ODA') and to multilateral institutions. ODA receipts comprise disbursements by bilateral donors and multilateral institutions."

Distribution of philanthropic and development aid funding

While comparable in size, ODA and philanthropic funding have targeted different parts of the world (Fig. 2). Nearly half of philanthropic funding between 2010 and 2014 supported North America-based work, primarily in the United States and Mexico (Fig. 3). In contrast, the largest recipients of ODA ocean-related grantmaking were in Africa (45 percent), Asia (21 percent), and Oceania (17 percent). This distribution of aid coincides with the sector's concentration on poverty alleviation and economic development in low- and middle-income countries.

The geographic split between ODA and philanthropic funding may now be starting to narrow. As discussed in closer detail in the next section, it appears the philanthropic sector is diversifying its funding to include a higher proportion of grantmaking in countries outside of North America and Europe, particularly in parts of Asia and South America where the aid community is heavily engaged.

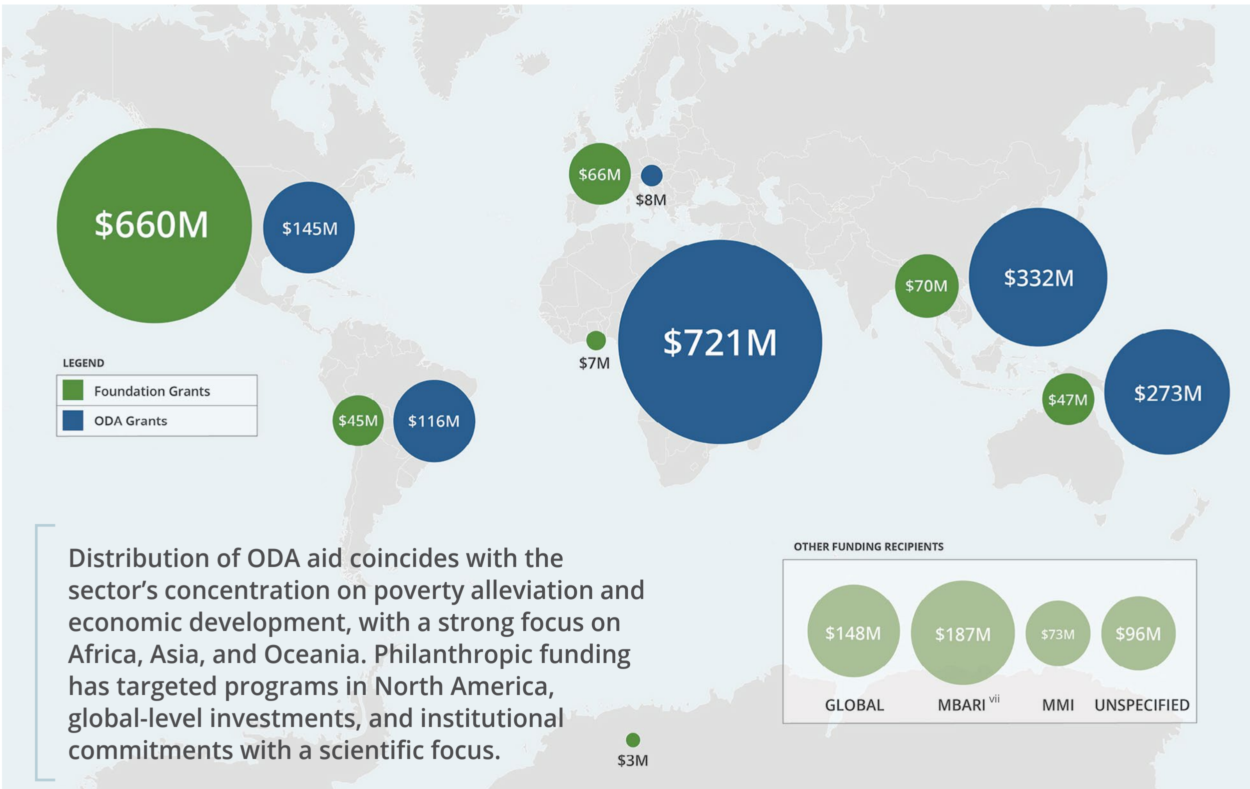
Source data for analysis in this chapter were gathered from grant-level data provided directly by participating foundations; supplemental information came from the Foundation Center's new database on ocean conservation funding. ODA funding data was gathered from the Creditor Reporting System (CRS) database maintained by the Organization for Economic Cooperation and Development (OECD). All grants are reported based on commitment amounts for a given year, rather than disbursements. Additional detail on methodology is provided in Appendices A and B.

Geographic Distribution of Philanthropic and ODA Grantmaking Between 2010 and 2014, in USD Millions | FIG. 2

		PHILANTHROPIC FUNDING		ODA FUNDING	
	LOCATION	FUNDING AMOUNT	% OF FUNDING	FUNDING AMOUNT	% OF FUNDING
CONTINENT	Africa	$7M	0.5%	$721M	45.2%
	Antarctica	$3M	0.2%	$0	0%
	Asia[ii]	$70M	5.0%	$332M	20.8%
	Europe	$66M	4.7%	$8M	0.5%
	North America[iii]	$660M	47.1%	$145M	9.1%
	Oceania	$46M	3.3%	$273M	17.1%
	South America	$45M	3.2%	$116M	7.3%
OTHER	Global	$148M	10.6%		
	MBARI[iv]	$187M	13.4%		
	MMI[v]	$73M	5.2%		
	Unspecified[vi]	$96M	6.9%		

ii. Includes funding to Indonesia, the largest philanthropic recipient country.
iii. Includes the United States, Canada, Greenland, Mexico, and Central America and Caribbean countries.
iv. MBARI: Monterey Bay Aquarium Research Institute
v. MMI: Marine Microbiology Initiative
vi. Indicates insufficient detail to categorize grant by geography.

Total Ocean-Related Grants from Philanthropic versus ODA Funding, 2010-2014 (in USD Millions) | FIG. 3



[vii.] Grants related to the Monterey Bay Aquarium Research Institute (MBARI) and Marine Microbiology Initiative (MMI) were differentiated as they encompass cross-cutting geographies and are heavily science-oriented. MBARI is a nonprofit oceanographic research center founded by the David and Lucile Packard Foundation. The Foundation supports approximately 80 percent of MBARI's annual US $50 million budget for the institution's work on cutting-edge research and development in oceanography. The Gordon and Betty Moore Foundation's MMI, which has issued US $228 million in grants since 2004, "seeks to gain a comprehensive understanding of marine microbial communities, including their ecological roles in the oceans; their diversity, functions and behaviors; and their origins and evolution. The current focus of the initiative is to advance our understanding of marine microbial communities by enabling researchers to uncover the scientific principles that govern the interactions among microbes and that govern microbially-mediated nutrient flow in the sea."

B. Review of philanthropic funding trends

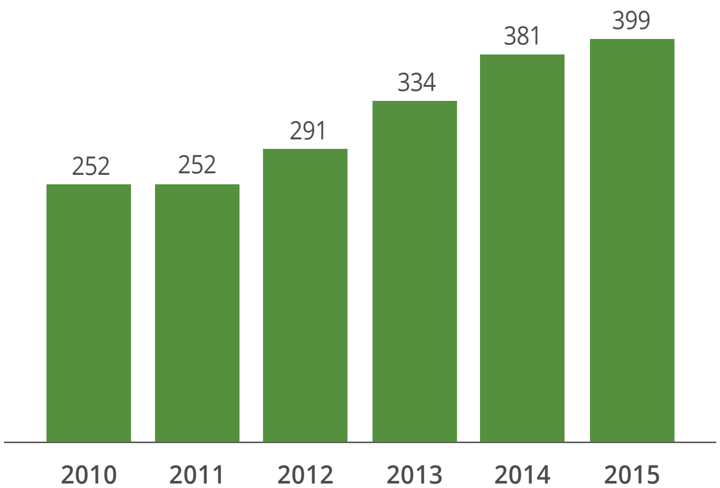
Ocean-related philanthropic grantmaking has been characterized by a few trends in recent years, including a steady increase in overall funding levels; the entrance of new foundations to the field; an increased proportion of total funding coming from grantmakers beyond the top-five largest funders; and a demonstration of interest in emerging issue areas, such as combating illegal, unreported, or unregulated fishing and using seafood markets as a tool to drive improvements in seafood production and management.

Distribution of philanthropic funding by issue area and region

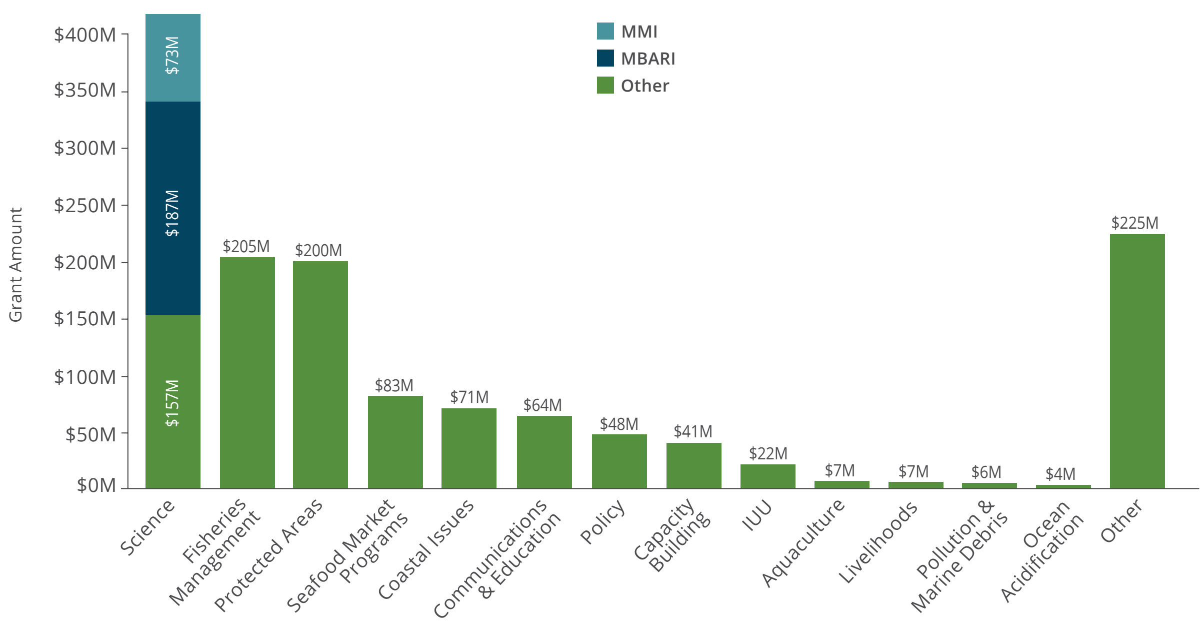
Overall, ocean-related grantmaking has steadily increased, from US $252 million in 2010 to an estimated US $399 million in 2015 (Fig. 4).[viii] This growth was driven both by ongoing commitments from the largest marine conservation funders and by the entrance of new funders to the field.

By issue area, the largest grant investments among foundations during the 2010-2014 period were in science, fisheries management, and protected areas (Fig. 5). While it is difficult to parse out the particular focus of work from grant descriptions, several specific areas of engagement are apparent, including work on seafood market programs and emergent topics such as IUU and ocean acidification. With respect to science, two large grantmaking initiatives (Packard's ongoing support for the Monterey Bay Aquarium Research Institute (MBARI) and Moore's Marine Microbiology Initiative (MMI)) were differentiated in this analysis as they represent major institutional commitments with a strong focus on scientific exploration.

Total Philanthropic Ocean-Related Grantmaking, in USD Millions | FIG. 4



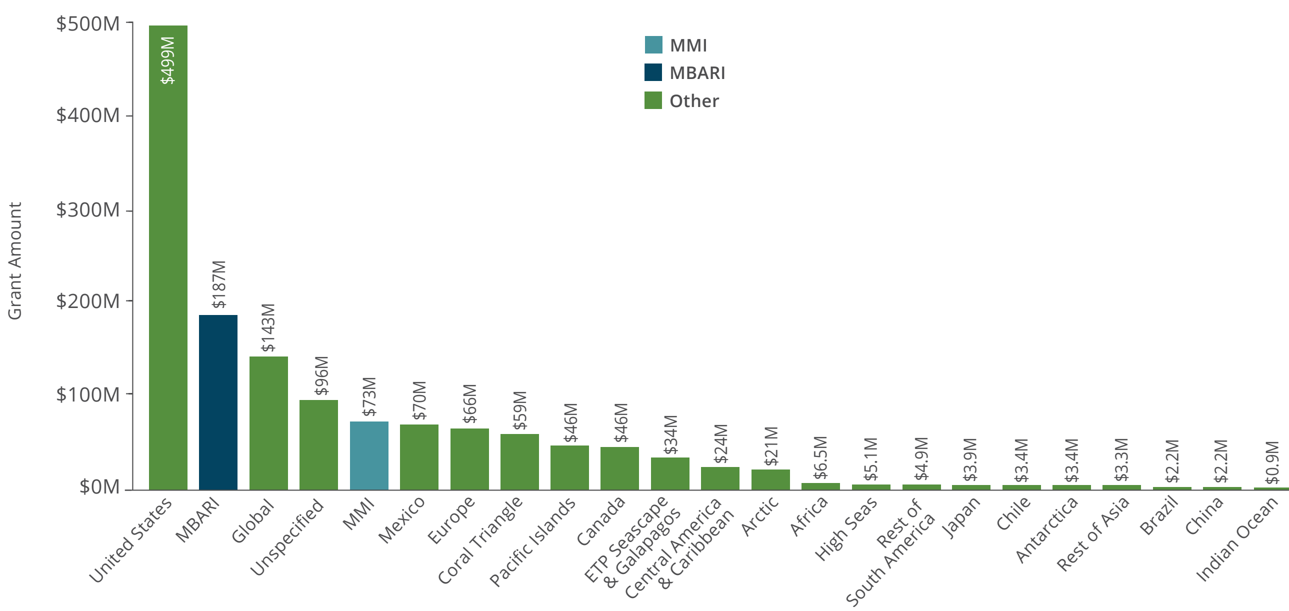
Marine Philanthropic Funding by Issue Area, 2010-2014 | FIG. 5



By geography, the United States received the largest concentration of philanthropic funding, nearly US $500 million, from 2010 to 2014 (Fig. 6). Efforts in the United States over that period include work on federal fisheries policy, marine spatial planning, catch shares, and region-specific efforts such as marine protected areas (MPAs) in California. At the country level, the second-largest recipient was Mexico, which received almost US $70 million in grants, with the largest support provided by the Walton Family Foundation, Packard Foundation, Oak Foundation, Helmsley Charitable Trust, and others to support a variety of issues, including protected areas and fisheries management. NGOs in the European Union collectively received over US $65 million from foundations, with sizable contributions from the Oak Foundation focused on fisheries management and seafood sustainability programs.

The Coral Triangle (which includes funding to Indonesia and the Philippines) and small island countries in the Pacific received US $59 million and $46 million, respectively, to advance fisheries reform, build capacity, and create and implement MPAs. Protected area support has historically been the main emphasis in this biodiverse region. That work has been anchored by the Walton Family Foundation's investments in the Bird's Head Seascape. The largest new funder in the Pacific region was the Bloomberg Family Foundation: its Vibrant Oceans Initiative included a commitment of over USD $50 million over five years to promote fisheries reform in the Philippines, Chile, and Brazil.

Marine Philanthropic Funding by Region, 2010-2014 | FIG. 6



> **Efforts in the United States include work on federal fisheries policy, marine spatial planning, catch shares, and MPAs in California.**

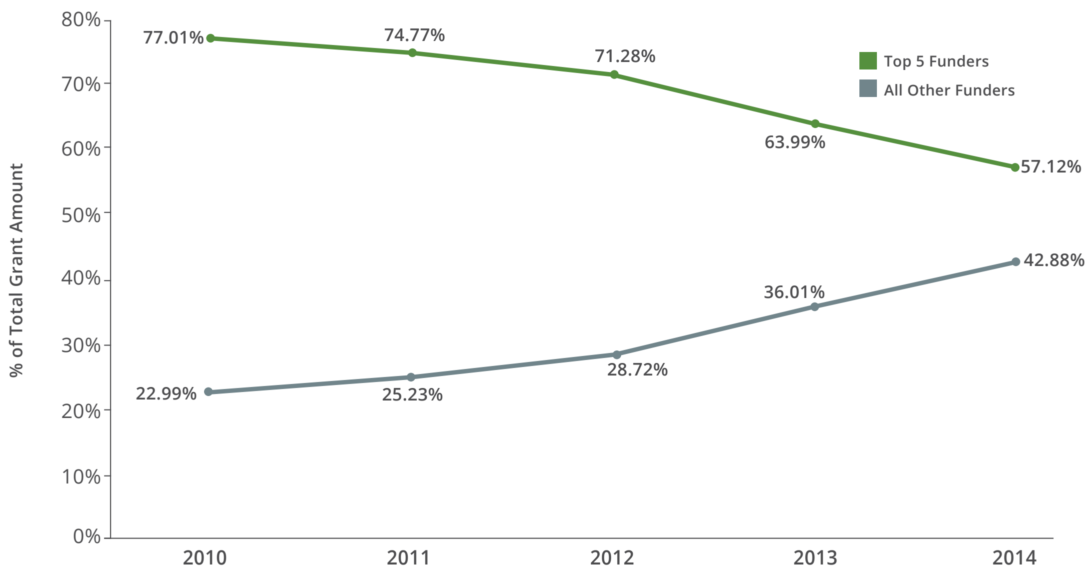
Closer examination of shifts and trends in the sector

A few themes have emerged in the field of marine conservation philanthropy in recent years:

1. **The five largest ocean funders continue to make up a significant share of overall ocean funding, but the entrance of new foundations is diversifying the field.**

   The top five ocean funders are the Moore Foundation, Packard Foundation, Walton Family Foundation, Marisla Foundation, and Oak Foundation. In 2010, these five foundations made up 77 percent of total ocean-related grantmaking (Fig. 7). By 2014, the proportion of total funding from these funders was 57 percent. Although the total grantmaking of the largest five funders has stayed constant, their share of marine grantmaking has declined with increased investment from other donors. A number of interested funders, both large and small, have begun turning their attention to ocean issues, such as Oceans 5, which was founded in 2011; the Bloomberg Family Foundation's Vibrant Oceans Initiative, launched in 2014; and the Rockefeller Foundation, which explored a grantmaking initiative on small-scale fisheries in 2014 (but did not launch a long-term grantmaking program). It remains to be seen whether these funders will remain in the field as part of a sustained investment or whether their involvement will be of a shorter duration.

Top Five Ocean Funders' Share of Total Grantmaking, 2010-2014 | FIG. 7



Note: "All Other Funders" contains grants from 279 funders that were not the among the top 5 in total grantmaking from 2010 to 2014. Large commitments from the Bloomberg Foundations have been distributed over multiple years. Grants from the Moore Foundation are factored in as disbursement amounts, rather than commitment amounts.

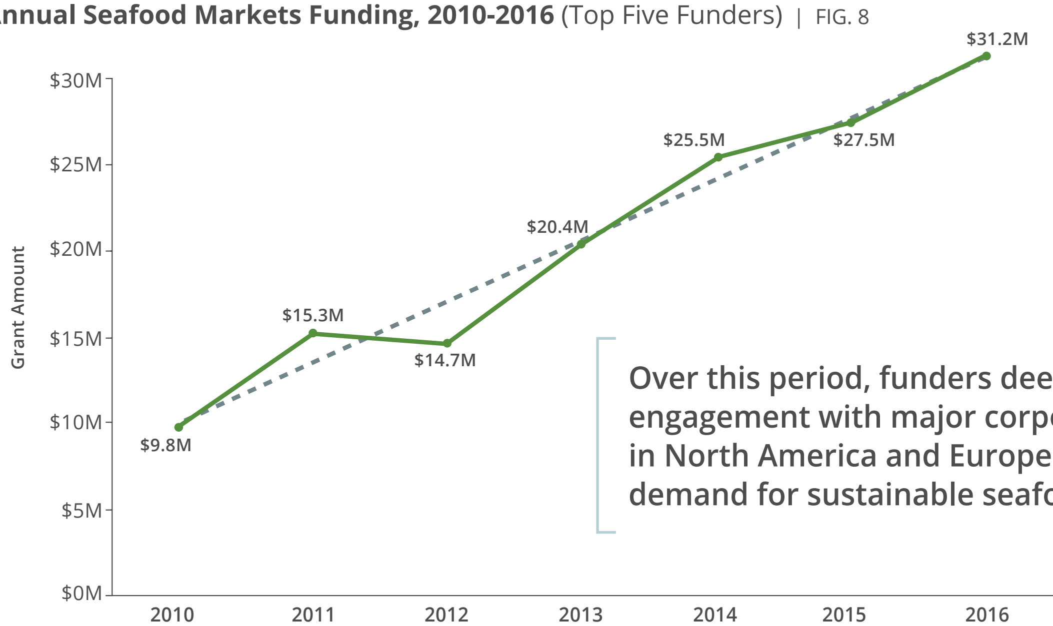
[viii] Total grants from the Moore Foundation show a smooth annual trend when viewed as disbursement amounts, but are highly variable year-to-year when plotted as commitment amounts. As this was not the case for most other large funders, grants from the Moore Foundation are shown as disbursement amounts in all charts that display a trend over time. For nontemporal charts, Moore Foundation funding is included as commitment amounts. For all other foundations, grants are shown as commitment amounts in this report.

2. As the nature of marine-related challenges evolves, funders are adapting their intervention approaches. Supporting market-based incentives for the sustainable management of fisheries and aquaculture is one area that attracted increased attention and funding since 2010.

Investing in seafood markets is not a "new" approach; the Packard Foundation has been supporting work to transform seafood markets since 1998, and several other foundations have sought to leverage market power to drive reform in fisheries management and production.

Yet grant investments in seafood markets from the top five funders increased from US $10 million in 2010 to US $31 million in 2016 (Fig. 8). Part of this increased interest in markets was associated with funders evolving their theories of change and adapting tools that were applied in North American and European markets. Over this period, funders deepened their engagement with major corporate buyers in North America and Europe to build demand for sustainable seafood. As several foundations expanded their work to address fisheries management in low- and middle-income countries, they also employed a variety of market options, such as fishery improvement projects (FIPs). The five organizations receiving the largest share of seafood markets funding among contributions between 2010 and 2016 are shown in Figure 9.

Annual Seafood Markets Funding, 2010-2016 (Top Five Funders) | FIG. 8



Over this period, funders deepened their engagement with major corporate buyers in North America and Europe to build demand for sustainable seafood.

Note: Grants from the Moore Foundation are factored in as disbursement amounts, rather than commitment amounts.

Top Grant Recipients of Seafood Markets Funding, 2010-2016 | FIG. 9

ORGANIZATION	USD $
Sustainable Fisheries Partnership	$8.8M
World Wildlife Fund	$8.0M
Marine Stewardship Council	$7.8M
Monterey Bay Aquarium Foundation	$5.0M
FishWise	$2.6M

This table refers only to grant contributions from the top five largest marine funders.

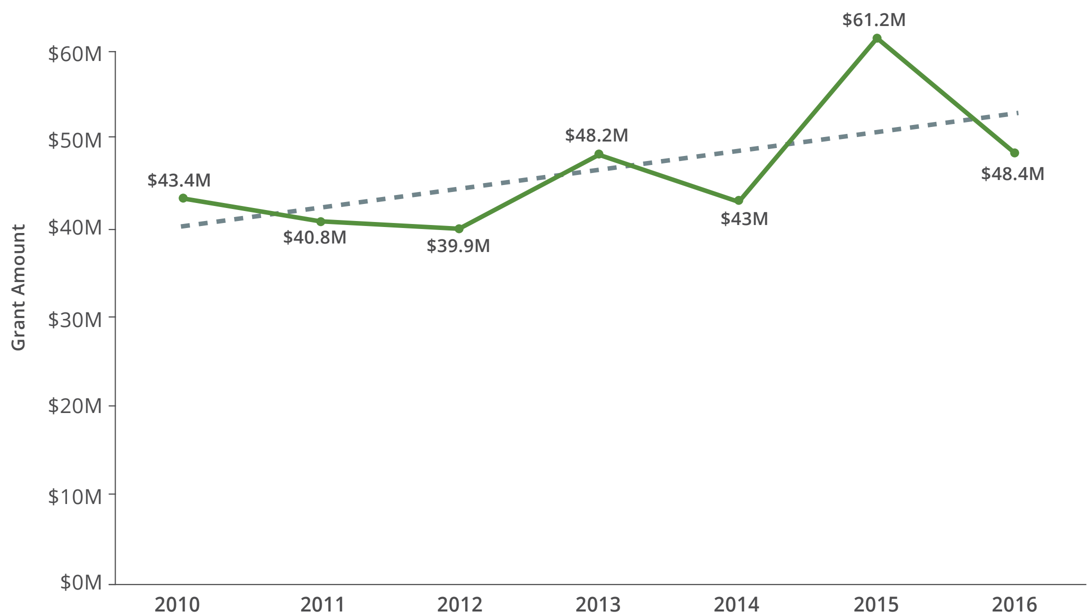
3. **The largest funders' grantmaking for protected areas has fluctuated in recent years. Based on current foundation strategies and theories of change, efforts to create new MPAs may receive less support from top funders in future years.**

Between 2010 and 2016, funding for marine area work averaged US $46 million among the top five ocean funders (Fig. 10). Funding peaked in 2015, which is mostly attributed to an increase in funding by the Oak Foundation to the Mesoamerican Reef Fund and a US $7 million increase in funding by the Moore Foundation for marine spatial planning efforts. Aside from this spike in 2015, it appears that MPA funding is mostly flat and is likely to decline in light of recent strategy refreshes.

The Oak Foundation, for instance, a long-term funder of protected area work in Mesoamerica, has indicated it will exit the region. Similarly, Packard's long-term support for the establishment and implementation of the California Marine Life Protection Act will ramp down with the successful creation of the MPA system. Some foundations, such as the Walton Family Foundation, are transitioning their funding of MPAs to support management by local entities. The Foundation has committed US $15 million in partnership with USAID to collaborate on a range of fisheries management initiatives in Indonesia, one component of which includes the Blue Abadi Fund, the largest dedicated marine conservation fund in the world. This investment is aimed at supporting the sustainable transition to local management.

Funding for protected areas is likely to remain an important component of select foundation portfolios, even if the overall funding for the issue tapers off in future years. The Moore Foundation, for instance, will likely continue to fund habitat protection, including planning, in North America. In the larger context of fisheries management, biodiversity conservation, and contribution to livelihoods, many foundations will continue to rely on MPAs as an important element of the solution set.

Annual Protected Areas Funding, 2010-2016 (Top Five Funders) | FIG. 10

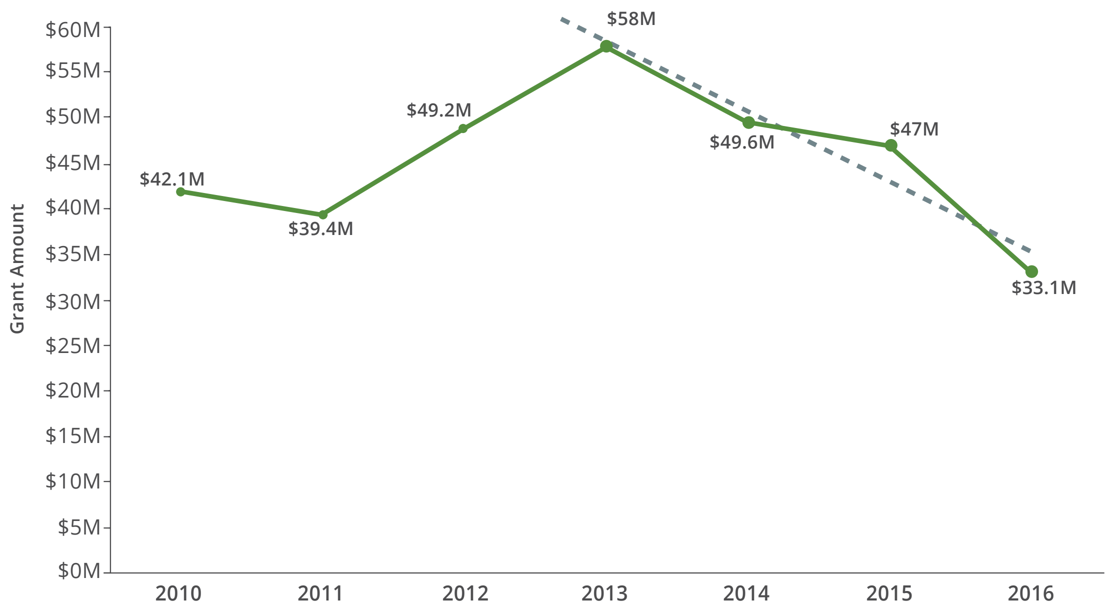


Note: Grants from the Moore Foundation are factored in as disbursement amounts, rather than commitment amounts.

4. Funding for U.S. place-based programs has fluctuated as a percentage of total place-based funding among the top five funders. As foundations become increasingly engaged in grantmaking abroad, U.S. programs may experience a decline in future years.

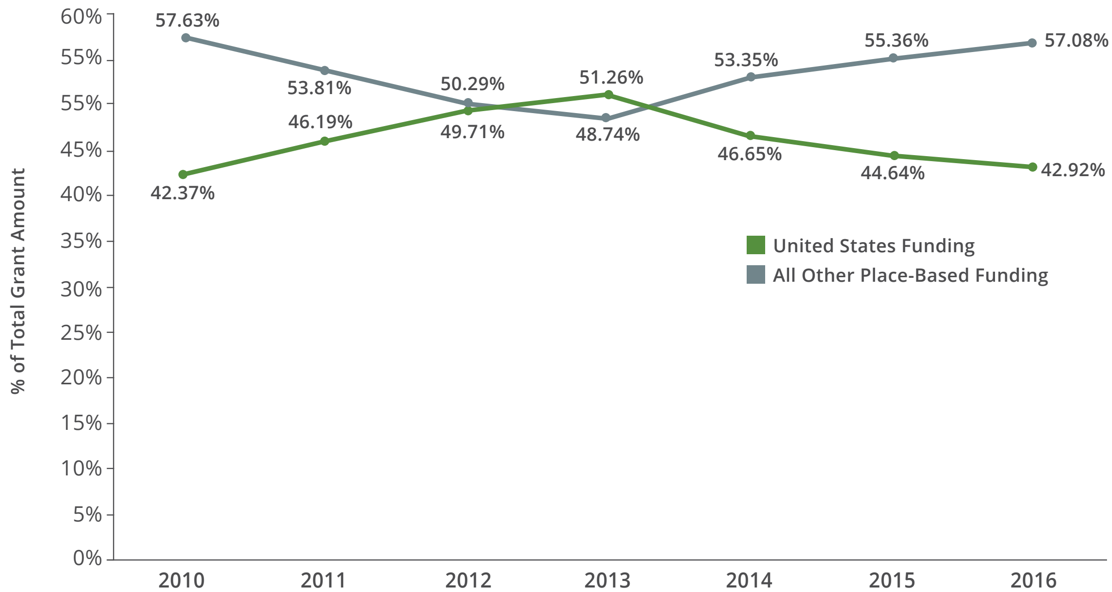
Among the top five funders, grantmaking to U.S. programs decreased from US $42 million in 2010 to US $33 million in 2016, though this decrease began in earnest after U.S. place-based funding peaked at $58 million in 2013 (Fig. 11). This decline is primarily driven by decreases from the Moore Foundation and Walton Family Foundation; funding from the Oak, Packard, and Marisla foundations stayed relatively constant during this timeframe. As a percentage of total place-based funding, the proportion of funding for U.S.-based programs declined to 43 percent of total funding in 2016, down from a high-water mark of 51 percent in 2013 (Fig. 12). This trend is likely to continue as funders are increasingly turning to new geographies or deepening their presence in place-based programs abroad, including North Asia (e.g., China, Japan, and Korea), South America (e.g., Chile, Brazil, and Peru), and existing priorities in Indonesia and Mexico. Still, many foundations will continue to maintain at least some level of engagement in U.S. programs, as they agree that work remains on several issues, including the Magnunson-Stevens Act implementation and protection.

Annual Grantmaking to Programs in the U.S., 2010-2016 (Top Five Funders) | FIG. 11



Note: Does not include grants to MBARI or Moore's MMI. Moore grants are factored in as commitment amounts, rather than disbursement amounts.

Place-Based U.S. Funding as a Percent of Total Place-Based Funding (Top Five Funders) | FIG. 12



Note: Does not include grants to MBARI, Moore's MMI, seafood markets programs, other global initiatives, or uncategorized grants.

Funders are increasingly turning to new geographies or deepening their presence in place-based programs abroad, including North Asia, South America, and existing priorities in Indonesia and Mexico.

State of sustainable finance in fisheries

Larry Band
Consultant/Director
California Fisheries Fund

Over the last five years, as philanthropic funders and NGOs have urgently searched for ways to accelerate sustainable management of the world's fisheries, many have promoted "finance" as a critical lever to drive change. Meaningful amounts of funding[i] have gone both toward clarifying what exactly we mean by "sustainable finance" in the fisheries context and toward promoting investments that would demonstrate how it works in practice.

Progress on both fronts has been slower than anticipated. Some of the more important clarifying questions this work has tried to answer include:

- **What role can non-grant funds play in pushing forward sustainable management of fisheries?**
- **How can the deep pools of commercial capital be brought to the table to meet the large funding needs of transitioning fisheries?**
- **How can grants, public funding, and impact investments be used to catalyze commercial capital involvement? What are the most effective "blended capital" strategies?**

While we have failed to establish clear consensus in response to these questions, there has been important progress in building foundational support for continued work on this topic. Most significant, there is now broad acceptance that sustainably managed fisheries can create substantial economic value in addition to environmental benefits. A number of academic studies and blueprint exercises have detailed this value-creation potential with a specificity and in a language that have engaged the more impact-oriented segments of the investment community.

This has encouraged a much more serious dialogue between sustainable fishery project sponsors, principally NGOs, and impact investors pursuing precedent-setting transactions. Further, it has driven efforts to form dedicated sustainable fishery funds including Althelia's Sustainable Ocean Fund,[ii] Encourage's Pescador Holdings[iii], and Rare's Meloy Fund.[iv]

[i.] The precise scale of funding available as "finance for sustainable fisheries" has not been catalogued to date, but likely extends into the single digit millions. Recent projects involving the philanthropic community include the following partnerships: International Sustainability Unit (ISU) and Vivid Economics; Bloomberg Philanthropies, Rockefeller Foundation, and Encourage Capital; and Moore Foundation, and Wilderness Markets.

[ii.] The Luxemburg-based asset management firm Althelia launched the Sustainable Ocean Fund in 2016. The fund plans to deploy US $100 million across a portfolio of 10-15 investments in sustainable fisheries projects, with a focus on developing countries. Conservation International and Environmental Defense Fund are serving as strategic partners for the fund.

[iii.] Encourage Capital and Zoma Capital announced the launch of Pescador Holdings, a sustainable seafood holdings company, in February 2017. The fund will start with an initial US $10 million commitment from Zoma Capital, which is the family investment office of Ben and Lucy Ana Walton. The launch of Pescador follows over two years of investment research supported by Bloomberg Philanthropies and The Rockefeller Foundation.

[iv.] The Meloy Fund for Sustainable Community Fisheries, an initiative of Rare, is a US $20 million impact investment vehicle that seeks to incentivize the development and adoption of sustainable fisheries through debt and equity financing to private businesses operating in the fishery wild-caught seafood and mariculture sectors. Its current geographic focus is Indonesia and the Philippines. Rare's investors and partners include Global Environment Facility (GEF), the Jeremy and Hannelore Grantham Environmental Trust, JPMorgan Chase & Co., and Conservation International, among others.

Unfortunately, these efforts have not yet led to a track record of successful transactions (especially in developing countries), a critical precursor to a scalable investment model. Despite the best intentions of both investors and investees, investors have been challenged to find a pipeline of "investment-ready" projects that offer an acceptable risk/return profile.

This may best be explained by the unacceptably high-risk profile of sustainable fishery projects. Projects are typically complex, relying on many entities working together to achieve shared outcomes. Project managers often have limited experience executing the strategies they seek to finance. Fish stocks and relevant ecosystems may not be understood adequately enough to support recovery projections. Relevant fisheries may only be in the very early stages of developing the policies and regulations that are critical to the expected financial and environmental outcomes. Project host countries may rank relatively low in terms of the general ease of doing business. Transactions are often smaller, with longer time horizons and less liquidity than investors prefer.

Moreover, impact-driven investors often struggle to clearly understand how their investment, sometimes one of many required to transition a fishery, will directly result in more sustainable management practices.

So how do we move forward from here to stimulate meaningful non-grant investment flows? I am skeptical that much progress will come from more systemic studies and high-level investment blueprints. We need to focus on the hard work of developing a robust pipeline of projects with an attractive risk profile for investors. The key to success will be building stronger risk-mitigation capabilities.

Toward this end, there are at least three initiatives worth pursuing:

- ***Support efforts to create a community of project developers,*** comparable to those we see in renewable energy, real estate, and carbon projects, that would work with sustainable fishery projects to address project execution risk. Organizations including Blueyou Consulting, Catch Invest, Future of Fish, and Wilderness Markets are exploring different ways to play the project developer role.

- ***Structure investments to best utilize philanthropic and public funds that can serve as first-loss or loss-sharing capital,*** in partnership with impact or commercial investors. Good examples include Global Development Facility (GEF) and U.S. Agency for International Development (USAID) commitments to the Meloy Fund as well as the proposed role of the GEF and the World Bank in a Seychelles Blue Bond.

- ***Support the adoption of sustainable fishery management policies that achieve environmental and social goals,*** while also allowing businesses and capital providers a path to competitive financial returns. (Rights- or tenure-based management systems attempt to find this balance, though they need to be designed with the appropriate social safeguards in mind.)

In addition, the pipeline-building process will benefit from considering more critically what types of projects are likely to benefit most from impact and commercial capital and focusing scarce resources on such projects. Can return-seeking capital play a role in catalyzing adoption of durable sustainable management systems, or do these systems need to be in place before return-seeking capital can be reasonably deployed? Is return-seeking capital best aimed at helping businesses realize the value of good management systems, versus implementing good management systems?

A more strategic use of philanthropy and other early-stage capital in fisheries reform

Miguel Angel Jorge
Senior Fisheries Specialist
The World Bank

After more than 15 years working with NGOs on marine conservation, I now find myself at the World Bank. My objectives have shifted from working with people to conserve marine biodiversity, to working on ocean sustainability to end poverty and promote shared prosperity. Over the years I've become increasingly convinced that this apparent reversal of means and ends simply represents two sides of the same proverbial coin. And yet historically, the conservation and development communities have been advancing their ocean agendas on two very separate financial tracks.

I would like to believe that marine conservation donors today embrace the idea that to ensure long-term protection of marine biodiversity, we need sustainable, productive economies free from poverty. This alignment of interests between conservation and development is much more than philosophical: if acted upon, it should leverage diverse financial and human resources and drive innovation and greater positive social and environmental impact.

In marine capture fisheries, the downward spiral of overexploitation, worsening poverty, and vulnerable coastal communities is repeated across the world. The forgone benefits from poor fisheries management total about US $83 billion a year globally.[1] These "sunken billions" are significant given that marine fisheries provide an important source of food and livelihoods for millions of people, but currently only add a net US $3 billion to the global economy. Thus, while the costs of improving fisheries management are significant, data show us that rebuilding and making better use of the ocean's natural assets generates far greater benefits.[2] Because fish provide a healthy and highly valued source of food for billions of people around the world, rebuilding fisheries should be a top priority for coastal and island developing nations seeking more jobs, secure communities, and private investment.

- **There is not enough experience using a blended capital approach of grants, development aid, and concessional lending to rebuild fisheries in ways that create sustainable and investible enterprises.**

What is far from adequate, however, is our knowledge of the mechanisms that will attract investors interested in not only financial returns but also positive social and environmental outcomes. There is not enough experience using a blended capital approach of grants, development aid, and concessional lending to rebuild fisheries in ways that create sustainable and investible enterprises, as few fishery projects have yet been designed with that specific outcome in mind.

To attract responsible capital we need to reduce risk in the fisheries sector. One way to reduce investment risk more quickly is to blend the agile funding of philanthropies with the deeper pockets of multilateral development banks (MDBs), including the World Bank. The more grantmakers begin targeting their capital toward the mutually reinforcing goals of healthy fish ecosystems and healthy fishing economies, the more likely they are to leverage larger sums of development aid and eventually private investment to sustain and expand their impact.

One pioneering example of this approach is being deployed in the Seychelles. Playing to their respective institutional strengths, the World Bank, the GEF, and The Nature Conservancy helped the Seychelles government create a mechanism to allocate the proceeds of the world's first sovereign "blue bond" to support the transition to sustainable fisheries. The blue bond, valued at US $15 million over 10 years with guarantees from the World Bank and GEF, will support sustainable marine resource management, infrastructure, and fishing enterprises, and will help identify high-value markets for seafood products. Strategic and collaborative up-front efforts such as these are essential to helping reduce risk quickly and attract more responsible investment capital. Unfortunately, many donors and conservation NGOs face internal incentives that do not necessarily encourage this kind of collaboration or look at the proverbial coin from the inverse perspective.

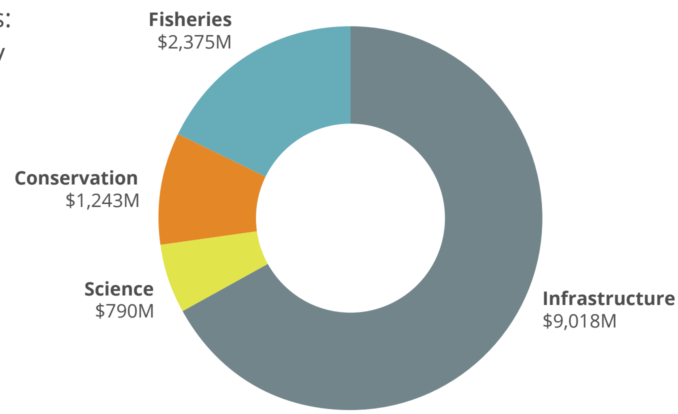
Responsible private capital and institutional investors are anxious to help recover the sunken billions, but we must first use early-stage funding from both the conservation and development communities more strategically, or we won't drive change fast enough.

C. Review of development aid funding trends

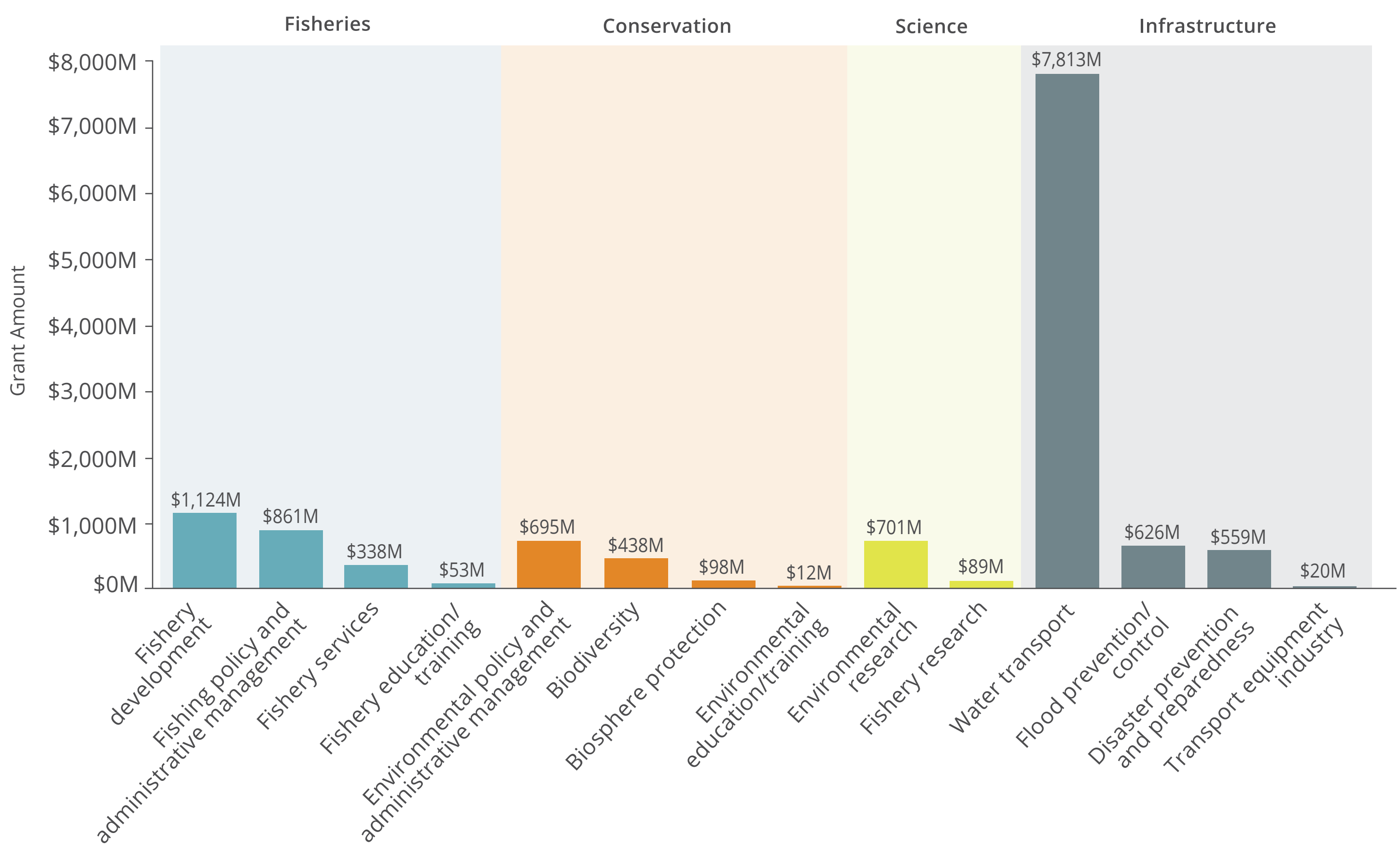
Ocean-related development aid funding

Development aid funding is disbursed in the form of grants, loans, and other flows (e.g., equity credits[vii]). A large portion of marine-related funding is oriented toward infrastructure projects: from 2010 to 2015, infrastructure made up nearly 70 percent of all marine ODA funding (Fig. 13). Within the category of infrastructure funding, "water transport" funding—which refers to projects such as port, harbor, and waterways improvements—was the dominant purpose, making up roughly 87 percent of funding (Fig. 14). Projects with the purpose code of "fisheries" accounted for about 18 percent of all marine ODA funding; about 84 percent of this subset of funding was allocated to fishery development, policy, administration, and management.

Marine ODA Funding by Category, 2010-2015 | FIG. 13



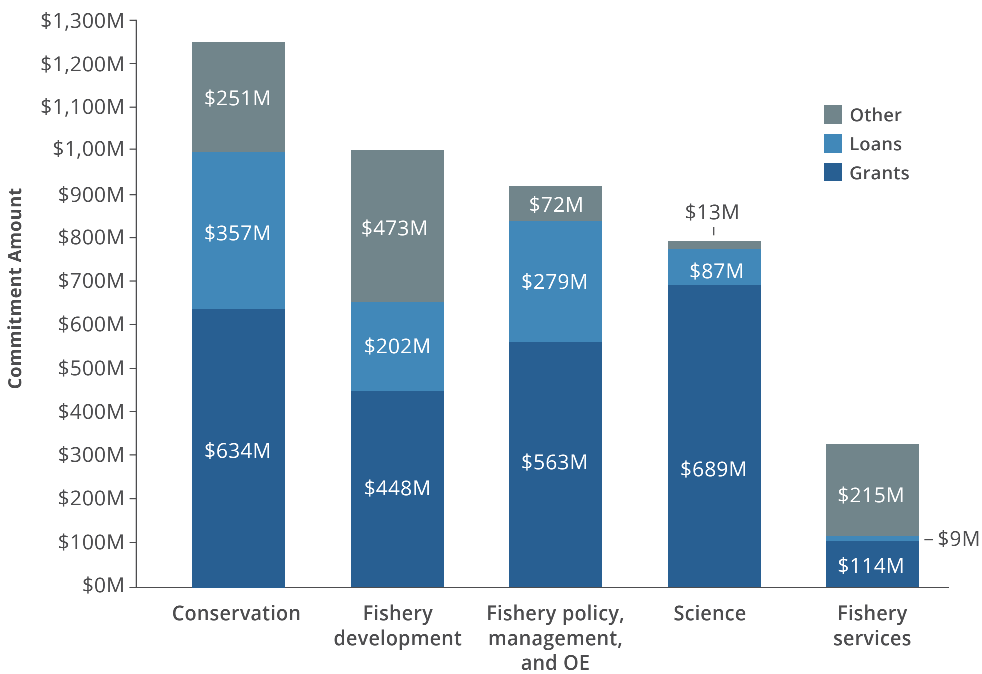
Marine ODA Funding by Purpose, 2010-2015 | FIG. 14



For the purpose of this report, infrastructure-related funding is excluded in order to enable a more in-depth review of fisheries, conservation, and science-related investments, which are considered to have closer alignment with philanthropic funding. Across marine ODA funding flows that exclude infrastructure investments, grants comprised 55 percent, while loans made up nearly 21 percent of funding from 2010 to 2015 (Fig. 15). The "other" category includes financial instruments such as export credits. For example, the majority of the US $473 million credit in the fishery development category came from a US $306 million export credit granted to the Philippines in 2014 to support the country in recovering from Typhoon Yolanda, one of the world's most destructive and deadly typhoons.

Excluding infrastructure investments, grants made up half of ODA funding flows; loans made up one-quarter; and "other flows" such as export credits comprised the remaining quarter from 2010 to 2015.

Relevant Marine ODA Funding by Category and Flow Type, 2010-2015 | FIG. 15



vii. According to the OECD, export credits are defined as "an insurance, guarantee, or financing arrangement which enables a foreign buyer of exported goods and/or services to defer a payment over a period of time. Export credits are generally divided into short-term, medium-term (usually two to five years repayment) and long-term (usually over five years)."

Review of ODA marine-related grants

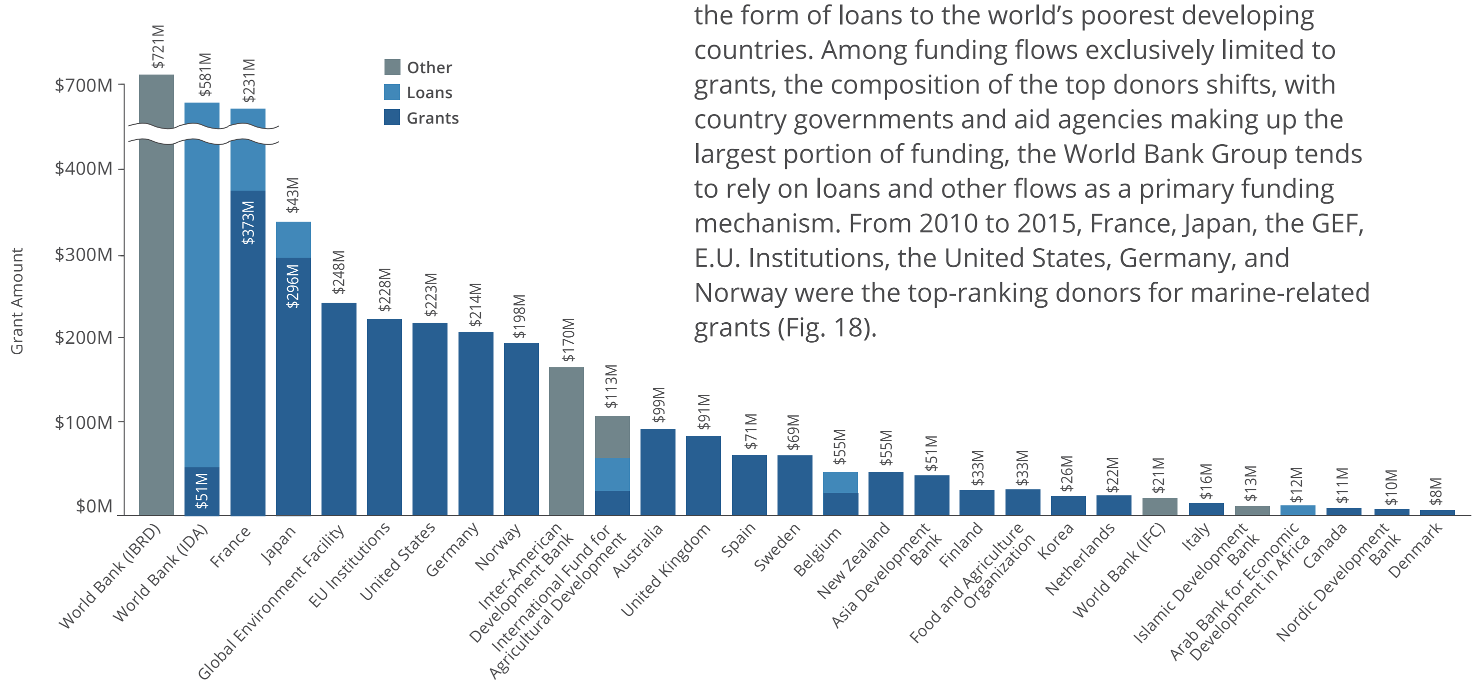
The aggregate level of funding for ODA grants varied modestly over the 2010 to 2015 period, increasing from US $339 million in 2010 to US $372 million in 2015, with a peak of US $467 million in 2011. Given the different types of funding flows that make up ODA funding—from grants and loans to export credits and equity investments—and the large size of major grants, the decline in grantmaking from 2011 to 2015 may not be indicative of a sustained trend. The 15 largest ODA grants are shown below, with a strong geographic emphasis on Africa and the high seas (Fig. 16).

The 15 Largest Marine-Related ODA Grants (2010-2015) | FIG. 16

RECIPIENT	DONOR	COMMITMENT (USD)	YEAR	PROJECT
Sub-Saharan Africa (Region)	Norway	$40M	2011	Nansen Program: Developing an ecosystem approach to marine fisheries in Sub-Saharan Africa
Namibia	Finland	$27M	2011	Fisheries research vessel to promote the fisheries industry in Namibia
High Seas	GEF	$27M	2011	Sustainable management of tuna fisheries and biodiversity conservation in areas beyond national jurisdiction
Lebanon	EU Institutions	$25M	2014	Protection and sustainable development of maritime resources in Lebanon
Africa (Region)	GEF	$25M	2011	Partnership for sustainable fisheries management in the large marine ecosystems in Africa
Mozambique	Norway	$24M	2013	Support to developing small-scale fisheries and aquaculture in Mozambique
North Africa (Region)	EU Institutions	$23M	2015	Marine protected areas in North Africa
ESA-IO (Region)	EU Institutions	$21M	2013	SmartFish implementation of a regional fisheries strategy in Eastern and Southern Africa and the Western Indian Ocean (ESA-IO)
Pacific Islands	United States	$21M	2015	Voluntary contributions to 16 Pacific Island States as part of the South Pacific Tuna Treaty
ESA-IO (Region)	EU Institutions	$20M	2012	Coastal and island biodiversity management in Eastern and Southern Africa and the Western Indian Ocean
Algeria	EU Institutions	$20M	2012	Sustainable development of the Algerian fishing sector
Mauritania	Germany	$20M	2012	Fisheries monitoring in Mauritania
South Pacific Islands	United States	$19M	2010	2010 contribution to the South Pacific Forum Fisheries Agency to strengthen sustainable tuna management capacity
South Pacific Islands	United States	$19M	2011	2011 contribution to the South Pacific Forum Fisheries Agency to strengthen sustainable tuna management capacity
Sub-Saharan Africa (Region)	Norway	$19M	2014	Nansen Program: Additional funding to develop an ecosystem approach to marine fisheries in Sub-Saharan Africa

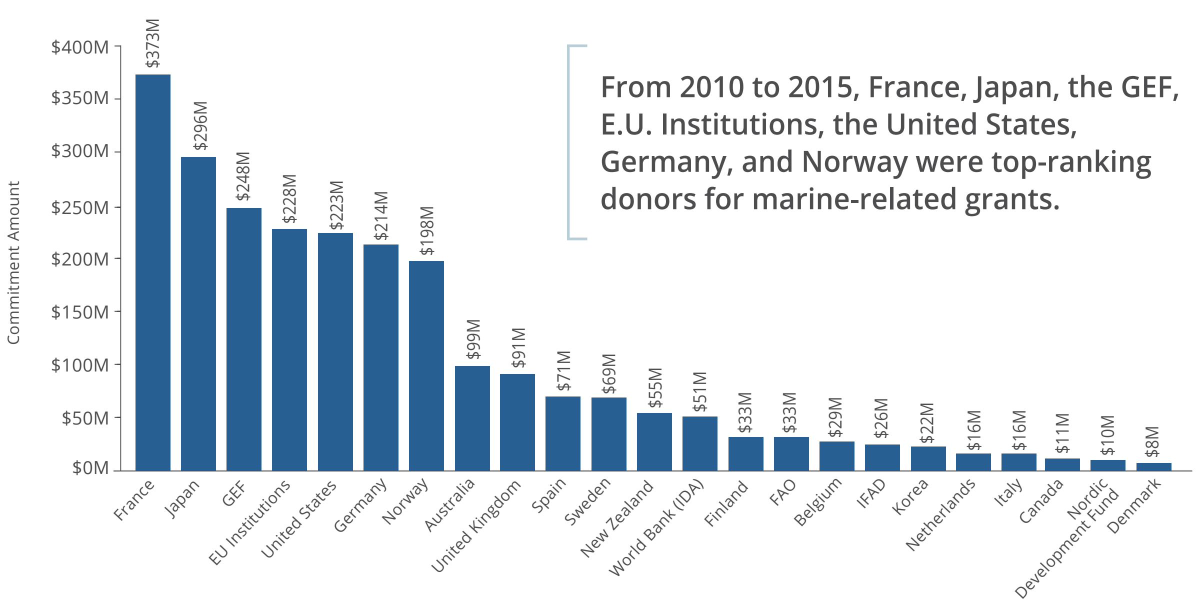
Factoring in all funding flows (including grants, loans, and other flows such as export credits), the World Bank is the largest donor for marine-related ODA funding (Fig. 17). The International Bank for Reconstruction and Development (IBRD)—which lends on commercial terms—accounted for the largest share, providing US $712 million in financial support to middle-income and creditworthy low-income countries in the form of loans, guarantees, and risk management products.

Largest Donors of Relevant Marine ODA Funding, 2010-2015 (>$5M) | FIG. 17



The International Development Association (IDA), which lends on concessional terms, accounted for the second-largest share, providing USD $581 million, mainly in the form of loans to the world's poorest developing countries. Among funding flows exclusively limited to grants, the composition of the top donors shifts, with country governments and aid agencies making up the largest portion of funding, the World Bank Group tends to rely on loans and other flows as a primary funding mechanism. From 2010 to 2015, France, Japan, the GEF, E.U. Institutions, the United States, Germany, and Norway were the top-ranking donors for marine-related grants (Fig. 18).

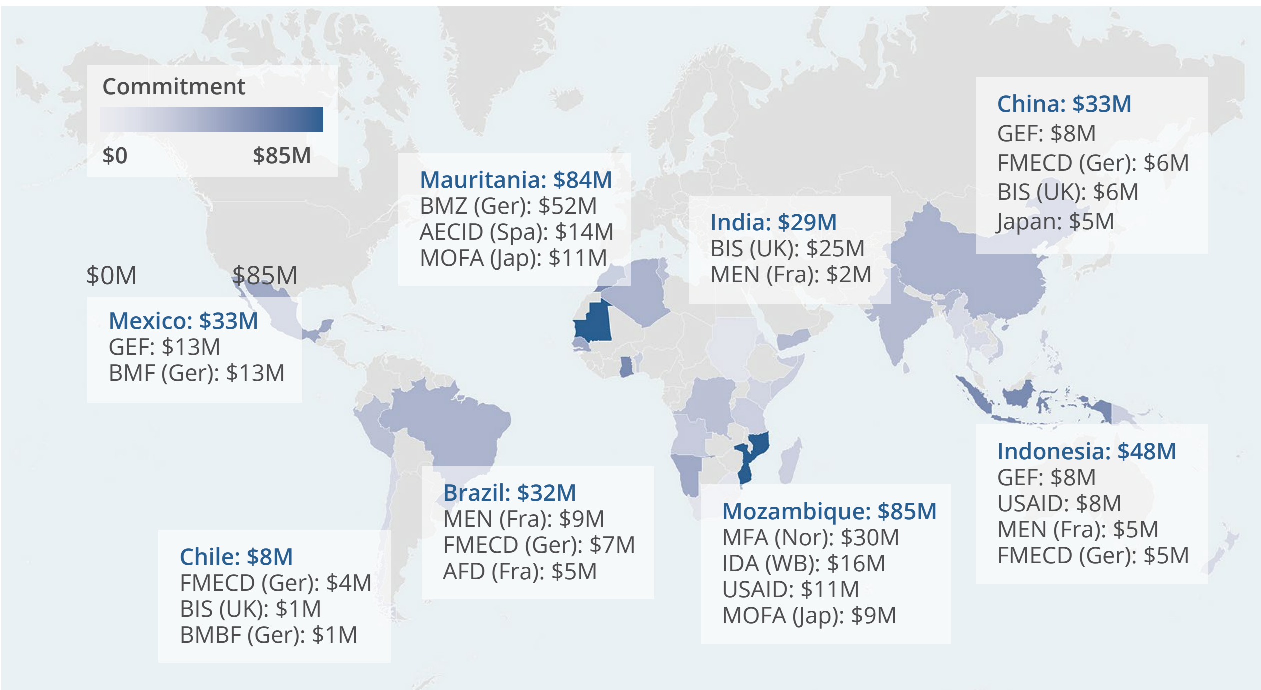
Largest Donors of Relevant Marine ODA Grants, 2010-2015 (>$5M) | FIG. 18



From 2010 to 2015, France, Japan, the GEF, E.U. Institutions, the United States, Germany, and Norway were top-ranking donors for marine-related grants.

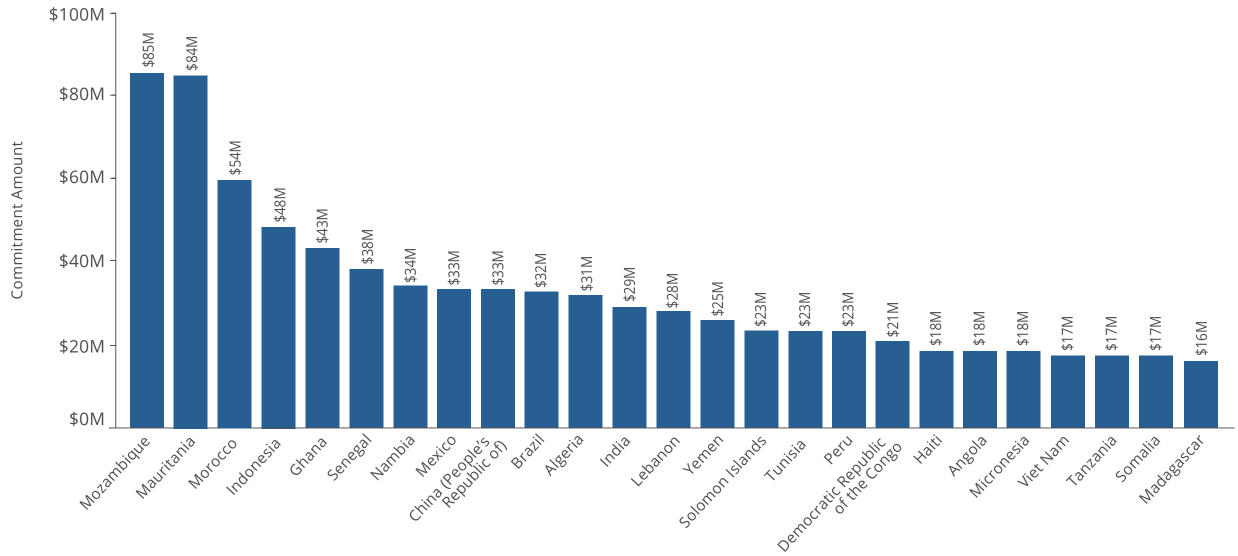
At a country level, the main recipients of marine-related grants are primarily located in Africa and Asia, with Mozambique and Mauritania receiving the largest share of ODA grants from 2010 to 2015 at US $85 million and $84 million, respectively (Figure 19). Among Asian countries, Indonesia was the top recipient of grant funding at USD $48 million, while Mexico received the greatest level of funding in the Americas, at US $33 million. At the regional level, Oceania received the largest share of funding at US $185 million, which highlights the development sector's prioritization of small-island developing states.

Top 50 Recipient Countries of Marine ODA Grants, 2010-2015 | FIG. 19

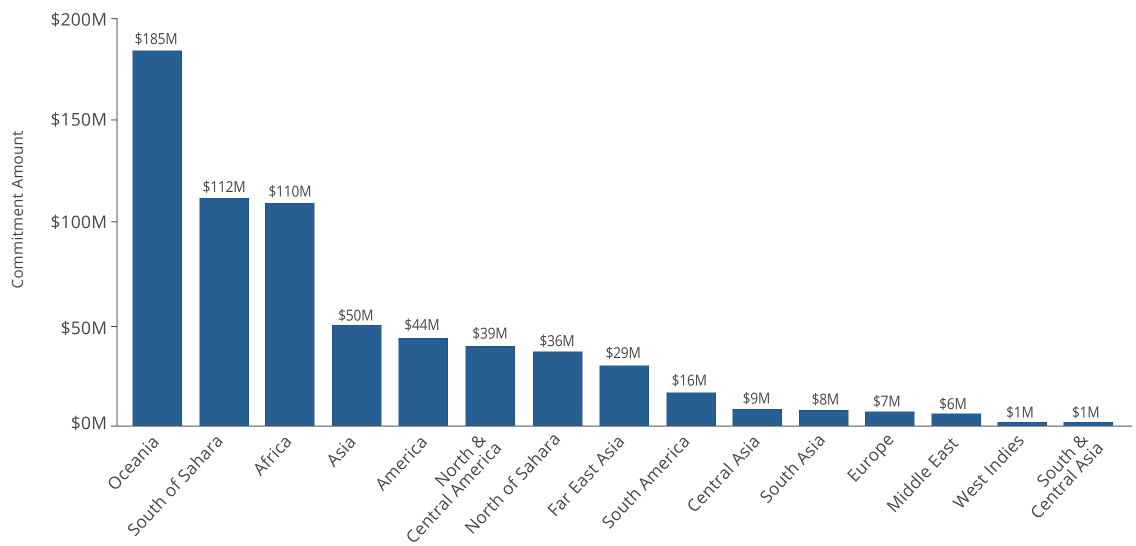


Call-out boxes indicate top donors for a selection of countries, with values in USD millions.

Largest Country Recipients of Relevant Marine ODA Grants, 2010-2015 (>$10M)



Largest Regional Recipients of Relevant Marine ODA Grants, 2010-2015



Note: ODA funding in the OECD database is categorized such that if a grant is provided to one country, it is attributed to that country. If a grant is provided to multiple countries, it is attributed to a region or subregion. This method is to avoid double counting. Thus, the country and regional charts in Fig. 19 should be interpreted as a corresponding set, rather than as two divisions of the same data.

A toolkit for philanthropy to understand development aid investments

Q&A with John Virdin

Director, Ocean and Coastal Policy Program
Nicholas Institute for Environmental Policy Solutions
Duke University

In this Q&A, CEA spoke with John Virdin about the priority-setting process, staffing structure, and funding flows for marine investments at the World Bank (the Bank). This interview provides a glimpse into the functioning of a key development aid institution by identifying how the Bank supports developing country governments to reform fisheries, reduce poverty, and improve fisheries management and governance.

Before transitioning to Duke University in early 2015, Virdin worked at the Bank for over a decade, including supporting the development of programs that provided more than US $125 million in funding for improved fisheries management in six West African nations and some US $40 million for fisheries and ocean conservation in a number of Pacific Island nations.

CEA: Can you tell us about the structure of funding flows and how the Bank prioritizes its investments in fisheries?

Virdin: Many of the world's poorest countries borrow from the Bank through IDA credits (concessional loans), or receive grants. These concessional loans offer the governments funds that wouldn't otherwise be available, because they can borrow below market rate, at zero or very low interest and with payments stretched over 25 to 40 years.

All of these IDA loans and grants will typically be based on a three-year strategy developed by the Bank with each government, usually called a "country partnership framework." In many cases, the development banks and other donors will collaborate to develop joint strategies to support a given country, based on principles of donor harmonization. So this means that development banks' lending decisions are largely decentralized and driven by discussions between the banks and governments (usually the ministry of finance), and dictated by these multi-year strategies aimed at reducing poverty over that timeframe.

If the fisheries sector is going to be financed by the Bank or any of the development banks, it will usually need to be prioritized in the Bank's multi-year strategy for support to each country.

CEA: How do fisheries "make the cut" on the investment list for development banks?

Virdin: A lot of the effort upstream in developing a project is to talk with the ministry of finance and other relevant government agencies and to make sure that the countries are prioritizing fisheries on their shortlist in the multi-year strategy. If fisheries do not make the cut in the shortlist of development priorities for the ministry of finance, and then subsequently into the Bank's support strategy, then it doesn't happen. This is a demand-driven and decentralized process; you really have to work at the country level to drive demand for fisheries reform on the ground.

CEA: What does the staffing structure at the Bank look like? Who is involved in making decisions related to fisheries investments?

Virdin: The Bank's technical staff are organized into global practices. In addition, there are country departments headed by Country Directors who are responsible for leading the day-to-day dialogue with the governments and determining the Bank's lending strategy in that particular country. The Country Director is the Bank's key decision maker for projects. He or she must sign off on all lending by the World Bank in the respective country, which is based on priorities articulated by the minister of finance and captured in the Bank's multi-year strategy for the country (i.e., the country partnership framework). Once that happens, the relevant technical staff from the global practices work with the country department and the government agencies to develop the investment.

CEA: Can you comment on the unique timelines that guide the work of the Bank and philanthropy?

Virdin: The Bank can make a long-term commitment in principle if not in actual funding. It might say, "This will be a series of loans for ten years, and we'll guarantee funding for the first five years now."

One of the challenges is that fisheries reform is on the decadal, not annual scale. Yet the Bank and other development banks are still a bank, and need to get money out the door to countries. So they have built-in incentives to do a smaller number of projects with a higher commitment amount, and to get it out the door fast—for example, a roads project. This is often more attractive than smaller projects to support governance of common pool resources like fisheries or forestry, which are areas that foundation might be able to help support.

CEA: Do you see any complementarity in the scale of the Bank's funding coupled with the potentially more flexible funding of foundations?

Virdin: Absolutely. The Bank's money is allocated to governments, and the results achieved are only as good as the efforts that governments put into implementing them. For example, Peru must fix its own fisheries, and the Bank staff can only encourage government accountability in reaching that goal and provide support to the government teams spending the funds.

In comparison, foundations have a lot more flexibility in that they do not have to go through the government or a three-year financing plan. They can just go out and directly fund research, local universities, and civil society. The two sectors can fund different types of things over different timescales, but you still must work at the country level.

The big picture is that the Bank has large amounts of capital for governments to work with, to support the transition costs of fisheries reform over time. There is a fundamental opportunity that foundations can meet: to drive demand at the government level for fisheries reform. This takes a lot of sustained engagement and consensus building. One alternative is for foundations to set up a seed fund to support the type of things that the Bank doesn't traditionally fund and to leverage development aid funding. This might mean working with the Bank to support macro/bioeconomic analysis upstream within the Bank and facilitate country-level analysis to identify good concepts and make the case for fisheries to be on the shortlist for investment funds. This approach is not guaranteed by any means and would take a long time to develop. Foundations wouldn't have as much control over spending as they normally have.

CEA: Let's say a foundation is interested in working with the Bank. Can you sketch out in practical detail what this would look like and how you start building those relationships?

Virdin: You need to start working together more on a day-to-day level. There might be five to ten Senior Fisheries Specialists at the Bank (maybe more) who are guiding strategy and lending on fisheries projects around the world. Find out who these people are, and then start working with them at the country level.

It's important to recognize that most people in these positions have busy schedules, so they may not immediately have the whitespace to have a monthly call with a foundation to talk about alignment. But if you can get connections to Bank staff at the country level, then a foundation could independently fund grantees in a way that supports the Bank's work in that country. Or they could form a foundation donor collaborative in a country, such as the Indonesia Marine Funders Collaborative.[viii]

I would say the Bank is receptive to interacting with foundations, but it will be largely ad-hoc, informal, and based on opportunities and relationships. It's difficult to do this across several countries; you really need to build one-off relationships. At a systematic level, this might look like a multi-donor trust fund that would provide funding across multiple governments.

CEA: What about studies like *The Sunken Billions*? Is it valuable for foundations to provide funding to support this type of research to influence funding priorities and policy goals?

Virdin: *The Sunken Billions* is helpful for raising the profile of fisheries and putting concepts in the hands of project teams. But you need to realize that all other sectors at the Bank are doing their own version of *The Sunken Billions* to make the case for their respective lost "billions." The Bank is facing 15 of these reports and it needs to whittle this down to four sectors on which to focus across its full lending portfolio.

While big research projects like *The Sunken Billions* provide helpful framing, it might be more worthwhile for foundations to develop concrete policy notes at the country level and to support sustained policy engagement through activities like in-country capacity building workshops and dialogue with governments.

[viii] The IMFC is a donor collaborative that provides marine funders a platform to discuss their mutual interest in the long-term health of Indonesia's marine ecosystems. Through this exchange, foundations have attempted to learn directly from fellow Indonesian colleagues, international experts, and each other about marine conservation work in Indonesia. The John D. and Catherine T. MacArthur Foundation, the Walton Family Foundation, the Margaret A. Cargill Foundation, and the David and Lucile Packard Foundation have been core members of the collaborative since 2012. Other foundations have occasionally joined these dialogues.

CEA: What do you see as the Bank's priorities for the next five to ten years?

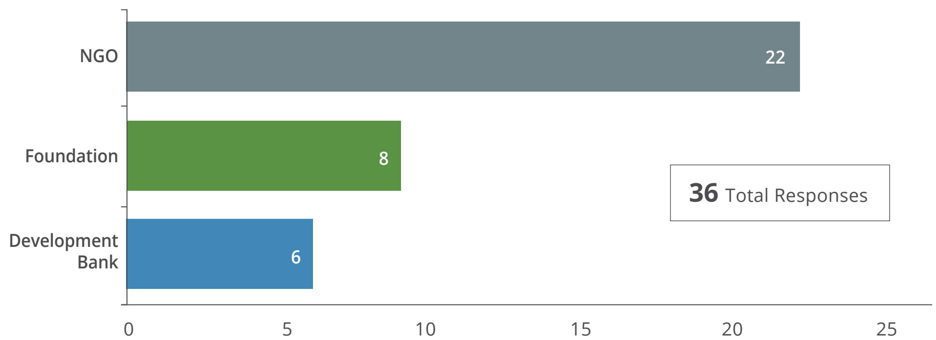
Virdin: In my own view, priorities may become very place-based and geographically oriented, not policy oriented at the global scale—based on the Bank's delivery model. Personally, I'd suggest three main priorities:

1. **Look for the biggest bang for the buck:** Where are the places with the need and opportunity to rebuild the largest portion of the world's fisheries and reduce the most poverty? I would literally take out a map and look for opportunities to grow the portfolio.
2. **Horizontally connect the dots (South-South coordination):** Are there opportunities to promote South-South learning and exchanges, and to set up structured processes for staff from, say the Solomon Islands to speak with Senegalese leaders? Connect leaders from the bright spots, rather than have it as a North-South-driven process.
3. **Communication:** Show that this is not hypothesis. You can invest in fisheries at scale, and it will pay off. I think we've gotten past the point of making the case that fisheries reform is needed and will have net economic benefits. We need large-scale demonstrations of how to apply this in the tropics, and the development banks are well-positioned to help do this.

D. Review of perspective survey with sector practitioners

To inform this report, CEA conducted a survey during January 2017 with the hope of better understanding the perspectives of leaders in the marine funding and NGO communities about trends in the sector and opportunities in the marine conservation space. A total of 36 individuals participated in the survey across the NGO, foundation, and development aid communities (Fig. 20). The findings are briefly summarized below.

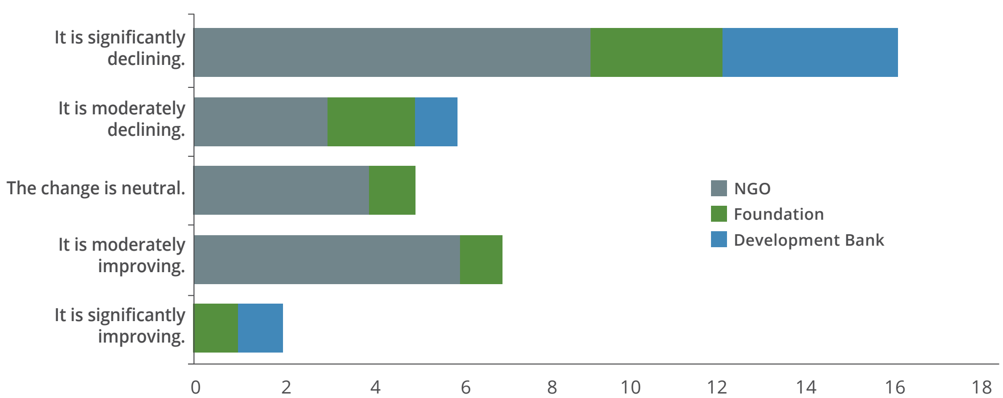
Number of responses by organization type | FIG. 20



1. Roughly two-thirds of respondents feel that the state of the ocean is in significant or moderate decline.

When respondents were asked how they perceive the direction of change for the state of the ocean, 44 percent said it is "significantly declining," while 17 percent said it is "moderately declining" (Fig. 21).

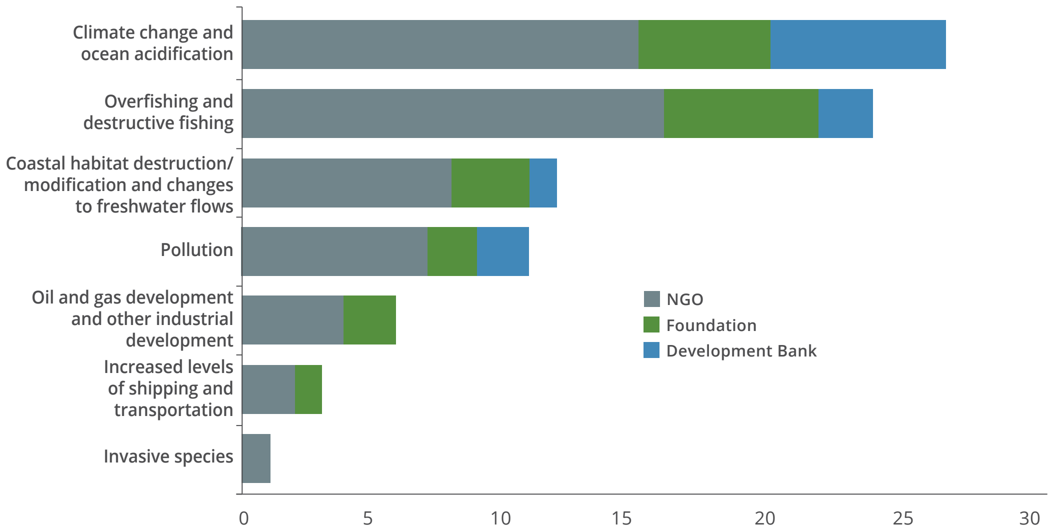
If you had to generalize, how would you characterize the direction of change for the state of the ocean? | FIG. 21



2. Organizations represented by the survey are largely focusing their work in the areas of fishing, climate change impacts, habitat destruction, and pollution.

Climate change and ocean acidification, as well as overfishing and destructive fishing, ranked as the top areas where organizations are currently prioritizing their work given the full spectrum of ocean-related issues (Fig. 22).

Among these threats, in which areas is your organization prioritizing its work? | FIG. 22



Note: Recipients were allowed to include their three top selections.

3. Participants provided a wide range of responses in identifying possible overlooked opportunities in marine conservation.

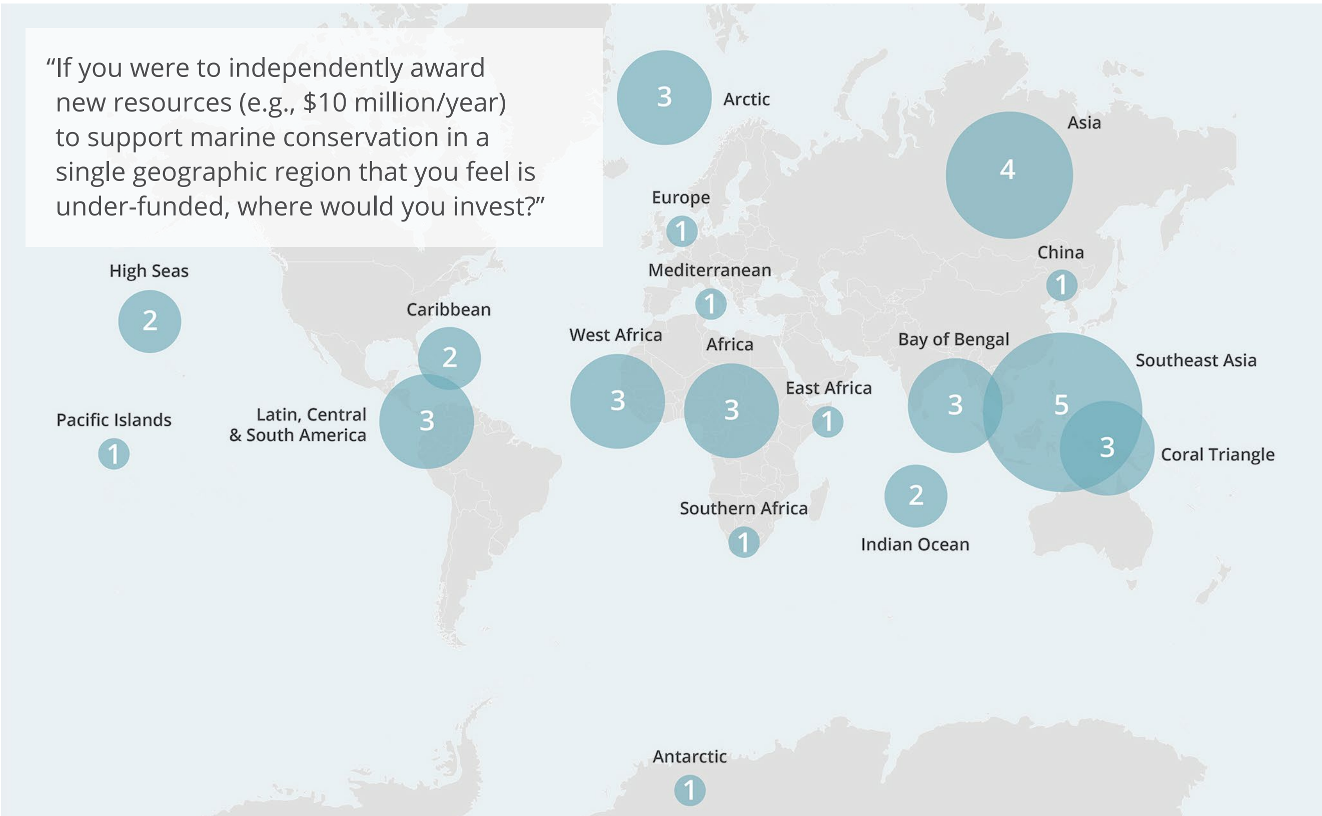
Survey participants were asked, “Can you think of a single major overlooked opportunity in the marine conservation space?”

Among NGO respondents, responses included more resources to middle- and low-income countries; ocean floor mining; the intersectionality of ocean health and other issues, such as human health; and improved coordination among NGOs.

Within foundation respondents, themes included increased coordination among foundations and NGOs; seafood sustainability and traceability; and phasing out harmful fishing subsidies.

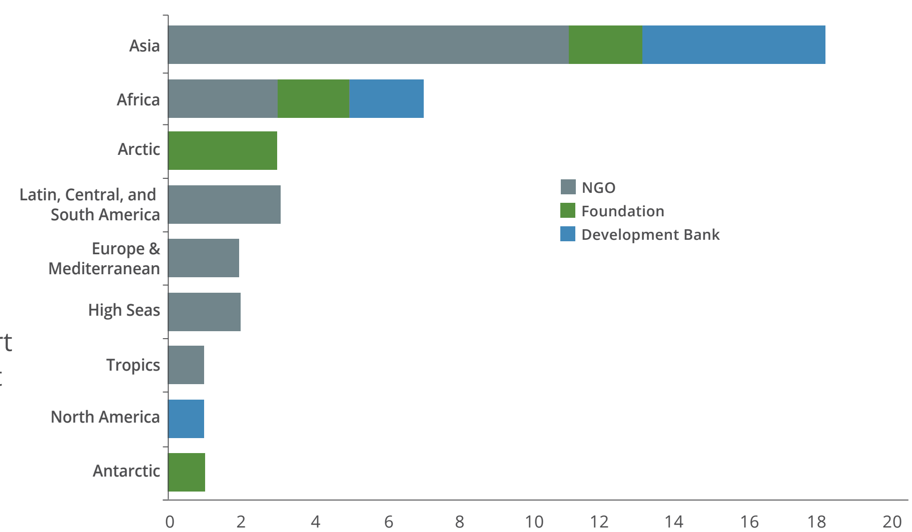
Representatives from development banks proposed the following opportunities: public messaging on the shared importance of ocean health; the contribution of fisheries to food security, nutrition, and livelihoods; and the opportunity to catalyze private-sector investment in ocean issues.

Distribution of where survey respondents would prioritize future marine funding | FIG. 23



4. Respondents would prioritize funding in Asia and Africa if they were awarded resources to advance marine conservation in a field they consider under-funded.

Survey participants were asked, "If you were to independently award new resources (e.g., US $10 million annually) to support marine conservation in a field that you feel is under-funded, where would you invest?" Fifty percent of respondents suggested a geography in Asia in response to this question, while nearly a quarter selected Africa (Fig. 23).



Marine fisheries and aquaculture

Global fisheries at a crossroads

Dr. Boris Worm
Professor
Dalhousie University
Halifax, Nova Scotia, Canada

The global ocean currently provides food and vital micronutrients to an estimated 3 billion people.[1] Centuries of intense fishing, however, have left a damaging imprint on ocean ecosystems,[2] resulting in a perilous state of global fisheries today, with uncertain prospects for the future.[3]

At the same time, there is unprecedented awareness of the need to rebuild depleted fisheries[4] and to better protect the ecosystems on which they depend.[5] Some affluent countries have taken steps toward fishery reform and improved regulation; as a result, however, additional fishing pressure has been placed on poorly regulated regions of the developing world and high seas.[4] As such, fisheries now stand at a global crossroads. Our individual and collective choices over the next decade will decide whether a majority of fisheries will stagnate, rebuild, or collapse. The consequences of these choices for marine biodiversity and human well-being can hardly be overstated.

The most recent analysis of all available catch and assessment data worldwide[6] confirms earlier studies[4,7-9] that showed the average state of fish stocks is indeed poor and declining. Of 4,714 fisheries assessed in 2012, only 32% remained at or above the biomass (total mass of fish left in the water) that supports maximum sustainable yield (B_{MSY}), while 68% have slipped below that critical threshold. Even more concerning is that only 35% of stocks are currently fished at a level that would allow for recovery. This means that most overfished stocks will experience further depletion, despite their compromised status. Significant regional variability in stock status mostly reflects regional capacities for assessment, management, and governance.[10] As of 2015, the United Nations Food and Agriculture Organization (FAO) confirmed that very few “underexploited” stocks remain, and most fisheries are stretched to the limit.[1]

Unsurprisingly, this leads to a gloomy global outlook under a business-as-usual scenario. When all available data are fed into a simple bioeconomic model, ongoing declines are projected for most fisheries, and widespread depletion is projected by 2050.[6] Assuming an instantaneous change in management for all stocks, two more optimistic scenarios emerge, which predict rebuilding under policies that maximize long-term catches or optimize long-term profit, respectively.[6] The upshot is that there is no controversy about where we should head: rebuilding of damaged fisheries makes sense ecologically, economically, and socially. But how do we get there?

The solution is very simple, in principle: we need to kill fewer fish and leave more animals in the water to contribute to population growth. To achieve this goal, the traditional management target of maximum yield should be treated as a limit that cannot be exceeded, rather than as a target that encourages stretching every fishery to the maximum. How is this done in practice? A review of 10 regions around the world that managed to initiate rebuilding showed that there is no silver bullet.[4] Creation of closed or protected areas, restrictions on certain fishing gears, and reduction in overall fishing effort were frequently used. Depending on local context, these measures were often combined with other tools such as community co-management, economic incentives, total catch regulations, or fisheries certification schemes. Without a doubt, it takes a range of management measures to transition fisheries toward sustainability, and custom solutions need to be applied to different places. But where this is done, we observe marked triple-bottom-line benefits in the ecological, social, and economic realms.[4,6]

One glaring constraint to effective fisheries management is IUU. While an earlier overview study estimated that about 20% of global catch is caught illegally,[11] a more recent country-by-country analysis showed that IUU catches may be as high as 53% of reported catch.[12] This latter compilation included not just illegal but also unreported recreational, artisanal, and unintended by-catch. These analyses confirm that this “dark side” of global fisheries looms large in tropical waters off Africa and East Asia,[11,12] but also in more northern hotspots in the Arctic, the Mediterranean, and the Black Sea.[12]

These challenges are still very much solvable, given that there have yet been very few global extinctions in the oceans, and a catalogue of proven solutions exists.

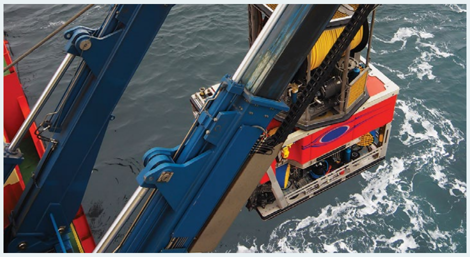
Some of these problems can be addressed by large, well-enforced protected areas, which are being established at a rapid rate and now cover about 4% of total ocean area.[13] Novel satellite technology helps us to track individual vessels and record their fishing activities through direct observation,[14] enabling more global enforcement and potentially further constraining IUU fishing. Another radical solution has recently been gaining more traction: by closing the entire high seas (areas beyond national 200-mile jurisdiction) to fishing, a large, globally connected refuge would be created, which could help to rebuild fisheries faster, create a global buffer against mismanagement, and provide long-term benefits to maritime nations.[15,16]

In conclusion, there is little doubt that (1) most fisheries have been overexploited in the past and continue to be overfished today, (2) rebuilding of depleted stocks has begun in some regions and has yielded large benefits, and (3) IUU fishing and the displacement of effort into poorly regulated regions represent critical challenges. These challenges are still very much solvable, given that there have yet been very few global extinctions in the oceans, and a catalogue of proven solutions exists. Furthermore, in the long term there is no trade-off between the well-being of fish, fisheries, and people. Many case studies show how these objectives can be optimized together, providing a blueprint for a more productive relationship between humans and the sea.

The global ocean in the context of national security

Rear Admiral Jonathan White
United States Navy (Retired)
President and CEO
Consortium for Ocean Leadership

It's not an exaggeration to say that the fate of life on our planet is inextricably tied to the fate of our ocean. The ocean is critical to our well-being, and to keep this precious resource healthy and productive, we must first understand it—its physical and chemical processes, the stressors it responds to, its complex ecosystems, and the interactions with the life it supports. This understanding is even more important because the ocean is changing in many ways not seen before in human history, which presents new challenges and opportunities to our nation as well as to our neighbors around the globe. The key to this understanding—which will lead to appropriate, evidence-based action to ensure our ocean's health (and therefore our survival)—is ocean science.



- **Ocean science extends beyond the scientific and Naval communities, playing a role in our security at all levels—national, homeland, food, and economic.**

From my 32 years as an active duty in the Navy (which culminated in my three-year appointment as Oceanographer and Navigator of the Navy), I can unequivocally tell you that ocean science has provided our nation with a tangible military advantage on, under, and above the sea for decades. In my current role as president and CEO of the Consortium for Ocean Leadership, I can, equally unequivocally, tell you that the value of ocean science extends beyond the scientific and Naval communities, playing a role in our security at all levels—national, homeland, food, and economic.

Investments in ocean science are of paramount importance given the ongoing, unprecedented change to our Earth system, especially now, when global population growth, particularly in coastal areas, stresses our ocean environment more and more every day. Unfortunately, these changes are happening at a time of increasing uncertainty regarding federal investment in ocean science. To advance our ocean knowledge that will enable necessary actions, we must use all available resources and reinvigorate public-private relationships and ventures. I believe there is much the philanthropic, NGO, and industry sectors can do (in collaboration with federal agencies, both in the United States and abroad) to ensure we grow, rather than lapse, our knowledge of the ocean.

One area where the philanthropic, NGO, and industry sectors can have a significant impact is IUU fishing, which has far-reaching security, human rights, and management implications. IUU fishing occurs when pirate fishers catch fish in violation of national laws or international agreements and treaties. There are clear links between IUU fishing and other transnational criminal activity,[1] specifically human, drug, and arms trafficking;[2] smuggling; and terrorism.[3] Rescued slave laborers report horrific conditions, including beheadings,[4] shootings, and tossing of sick shipmates overboard. Of 50 former slaves interviewed,[5] 29 reported seeing another trafficked worker killed. Do you think this sad story merely affects a far corner of the globe, and do you imagine you can't do anything about it? Well, you'd be wrong on both counts.

First, IUU fishing is a massive enterprise that corresponds to our growing seafood appetite worldwide. Fish provide more than 3 billion people with nearly 20 percent of their average per capita consumption of animal protein,[6] with demands only expected to increase in the coming decades. The issue extends far beyond a few handfuls of fish discretely making their way into the legal supply chain. Illegally harvested fish are estimated to represent 20 percent of the worldwide catch,[7] exceeding an annual value of US $23 billion.

Second, this illegal practice leads to national, homeland, food, and economic instability around the world. It's not a problem that starts and ends in an isolated region of the world. The 2004 al-Qaida terrorist bombings in Spain have been linked to IUU activities.[8] As the Arab Spring and recent events in Syria[9] illustrate, food instability, whether terrestrial or marine, is a catalyst for conflict that leads to mass migrations, political upheaval, and general instability. The practice also has drastic economic impacts. IUU fishers distort legal markets and unfairly compete with law-abiding fishers and seafood industries, undermining the 260 million legal fisheries jobs worldwide.[10] And if law-abiding fishers lose their jobs, IUU fishing can further push them to piracy for survival.[11] Finally, properly managing fisheries is critical if we are to have a healthy ocean with adequate fish stocks. With 90 percent of the world's fisheries fully exploited, over-exploited, or collapsed, this natural resource is already teetering on the brink.[12] With one-fifth of total global fisheries production coming from IUU fishing,[13] managers cannot make fisheries management plans based on accurate stock numbers, which results in even more overfishing and overexploitation.

Fortunately, there are steps we can take to address this problem and to help policymakers, law enforcement agents, and scientists in combating this global scourge. During this time of fiscal uncertainty, the public sector will be looking for increased opportunities for collaboration with the philanthropic community. How can you most effectively help solve this global issue? In the list below, I identify key challenges facing the ocean, opportunities for philanthropic or individual engagement, and the direct impacts that will result.

- **Problem #1: The ocean is vast, so even if we pinpoint where IUU fishing is occurring, it will still be nearly impossible to prevent it.**

Solution A: Better monitor and observe our ocean. Partner with groups that use and deploy new ocean sensors (or update old ones) to incorporate surveillance technologies that give these devices a secondary enforcement mission as more data are collected.

Result A: This approach results in two outcomes to address IUU fishing: improved predictions and better enforcement capabilities. An increase in data collection enhances maritime domain awareness, giving us an idea of where prime target stocks are (and will be) located. This will lead to better enforcement by allowing agents to monitor valued stocks and keep pirate fishers from operating in those regions, thus stopping the problem before it even begins. Another benefit of deploying more sensors is that we will obtain more data points on our ocean processes, which will lead to improvements in other arenas like weather forecasting and disaster response.

Solution B: Create a pilot project to improve data sharing from multiple sources, both public and private, to ensure all resources are being used as effectively as possible.

Result B: Such a project will enhance data collection, planning, and execution to coordinate and exercise response and mitigation opportunities. Additionally, it would ensure effective use of resources (e.g., money won't be spent collecting redundant data).

Solution C: Ensure compliance with the Illegal, Unreported, and Unregulated Enforcement Act of 2015,[14] which will advance efforts to keep IUU fish from entering the U.S. market, and support new measures taken by Congress and the administration to stop IUU fishing. Civil society can engage on this issue through constituents contacting U.S. senators and representatives, educating them on the issue, and affirming the importance of the issue. Individuals and organizations can also provide input in response to Federal Register solicitations.[15]

Result C: IUU fish will be kept out of the U.S. market.

- **Problem #2: Seafood fraud, where seafood is mislabeled for an economic gain, is a common problem.** An investigation by Oceana found that approximately one-third of all seafood tested in the United States from 2010 to 2015 was mislabeled.[16] IUU fishing and seafood fraud, while separate issues, overlap when a species is intentionally mislabeled to hide IUU activity. Fish need to be traceable along the supply chain, from hook to plate, to keep this from happening.

    Solution A: Partner with groups that are working to improve traceability from the moment a fish is caught. Build consumer demand for groceries and restaurants to sell only traceable seafood.

    Solution B: Apply ongoing research and technology associated with marine genomics to enable rapid sampling and subspecies identification that will indicate if seafood is from a sustainable, safe, and legal source.

    Result A/B: Reduced demand for nontraceable fish will result in supporting legal fisheries while simultaneously combating IUU fishing.

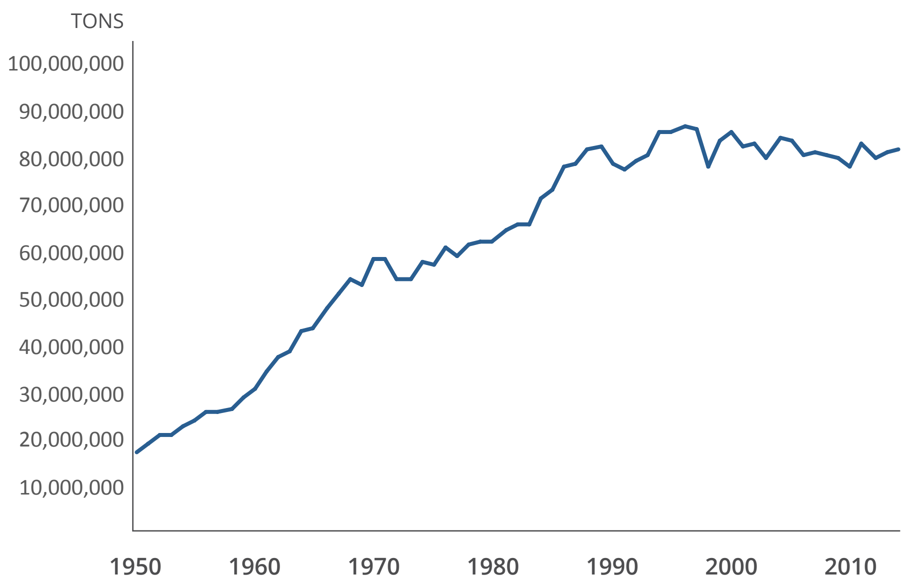
My final suggestion for the philanthropic community is one that applies to IUU fishing but is also a broader, more effective approach for any number of issues in our tight fiscal environment. Cooperative institute models, which are partnerships between research organizations (academic and nonprofits) and line offices within a federal agency, have proven to be an effective means to do more with limited resources. They create long-term collaborations between scientists across the public and private sectors and help train and educate the scientific workforce through the creation of fellowships. Collaborations such as these will be critical to maintaining our national, homeland, food, and economic security.

There are many ways to embrace ocean science to mitigate security risk in the United States and abroad. With limited federal dollars, collaboration and cooperation across the ocean science and technology communities will be critical to our ability to understand and respond to challenges and opportunities. IUU fishing isn’t the only problem that our ocean faces, but steps taken to address this will help solve some broader issues as well. In an increasingly connected world, IUU fishing in the far corners of the globe has real impacts to our country here and now. There are real safety, economic, and ecological consequences of waiting to take action. Together, let’s move forward to keep our ocean healthy and productive, and to ensure the survival of life–including human life–as we know it on our planet.

Global wild capture landings

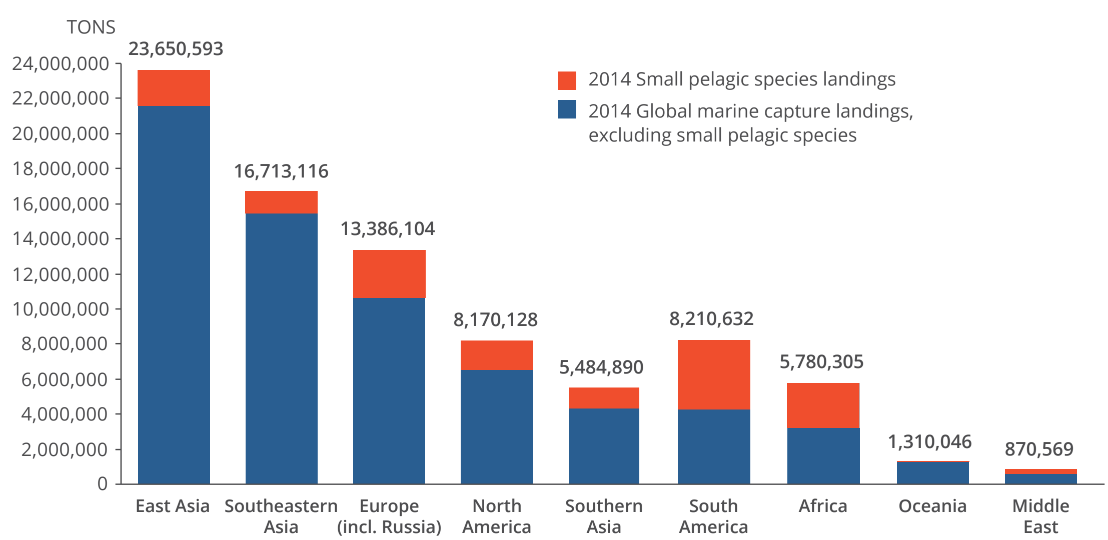
According to statistics from the FAO, global marine landings increased at a rate of 1.4 million tons per year from 1950 to 1990.[1] In 1996, global landings peaked at 86 million tons, plateaued, and are now decreasing at a rate of about 0.2 million tons per year (Fig. 1). East Asia and Southeast Asia have the highest landings, fueled by production in China, Indonesia, and Vietnam (Fig. 2).

Global marine capture landings (1959-2014)[i] | FIG. 1



Source: FAO FishStatJ, 2016

Total global marine capture by modified subregion | FIG. 2



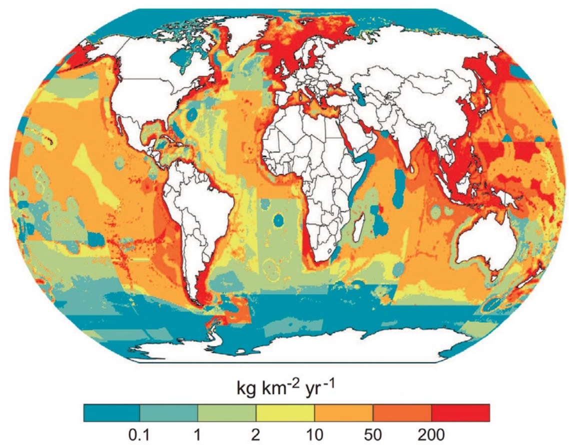
Source: FAO FishStatJ, 2016

[i] Excluded from Landings: blue whales, fin whales, brown seaweeds, corals, seals, walruses, green seaweeds, miscellaneous aquatic mammals, miscellaneous aquatic plants, pearls, shells, red seaweeds, river eels, sea squirts and other tunicates, sperm whales, pilot whales, sponges, and turtles.

There are important regional variations that may help explain shifts observed in global catch. In regions like much of Africa and South America, a decrease in the productive capacity of fisheries—as a result of overfishing—may account for the slowing trend in catch (Fig. 3). In order to return to historical catch potential, fisheries in these regions must allow for significant reductions in short-term catch.

Other areas of the world, particularly North America and parts of Europe, have already taken steps to rebuild depressed stocks, so fishing effort has been reduced since the 1990s to allow for stock recovery. Asian fisheries have maintained increases in catch[2] for several decades, despite evidence of indiscriminate overfishing practices. One reason for this sustained production may be the aggressive and nonselective approach of fishing out predatory fish, which has allowed prey to increase in abundance.[3] As shown in Figure 3 with red shading, certain areas of the world are highly productive, particularly East and Southeast Asia and Northern Europe.[4]

Average annual catch rates, including IUU (2010-2014) | FIG. 3



Source: Scientific Data, 2017

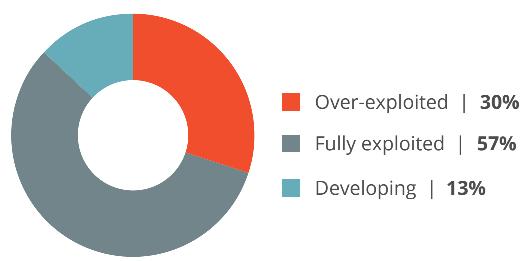
Global stock status

There are various interpretations of global stocks' current status as a result of limited data in key regions, use of different methodologies to assess stocks, and different perspectives as to what defines a sustainable fishery.

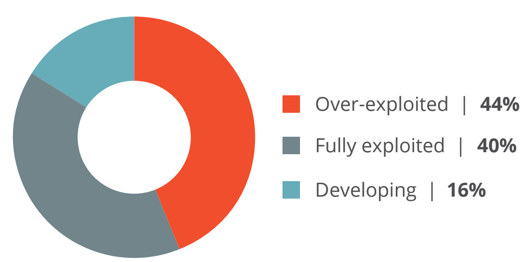
According to the FAO, global fisheries have maintained stock biomass slightly above B_{MSY}, on average. FAO bases its claims on stock assessments and expert opinion. It contends that roughly 57 percent of stocks were considered "fully exploited," 30 percent were "overexploited," and 13 percent were classified as "developing," according to the FAO global estimate (based on 2012 data), which comprised 80 percent of global catch (Fig. 4).[5]

An alternative perspective is provided by the Sea Around Us project (based out of the University of British Columbia), which uses catch history data to estimate the status of both assessed and unassessed stocks globally. The Sea Around Us data present a slightly more pessimistic portrayal of the state of stocks, with 44 percent of stocks considered "over-exploited," 40 percent considered "fully exploited," and 16 percent considered "developing."[6]

Percentage of stocks in each status (FAO, 2012) | FIG. 4



Percentage of stocks in each status (Sea Around Us, 2012)

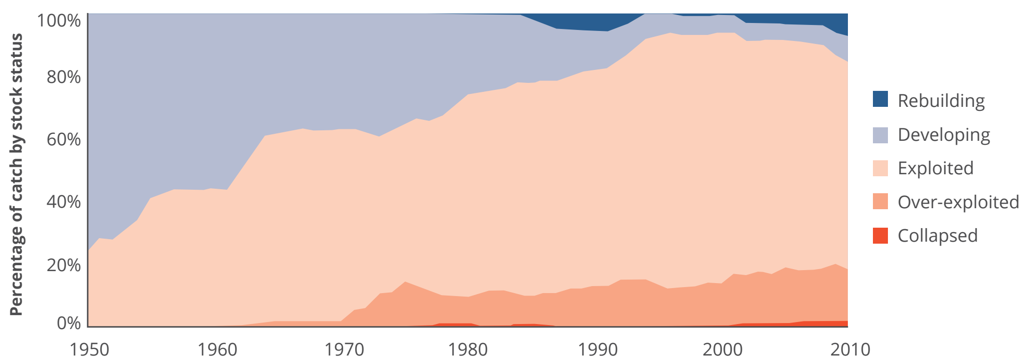


FAO catch data intentionally only tracks reported landings and thus may underestimate actual catch from artisanal (small-scale and commercial) and subsistence fisheries and omit consideration of recreational fisheries, discarded bycatch, and illegal and unreported catch.

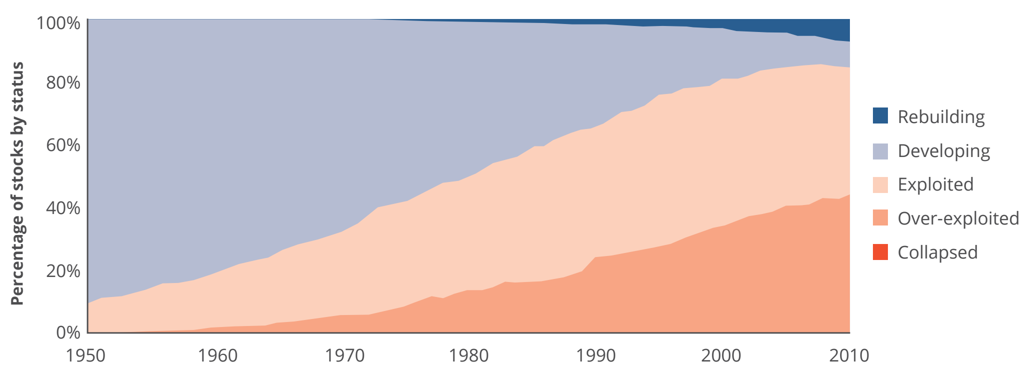
The Sea Around Us project is involved in "catch reconstruction" efforts to merge a variety of data and information sources to estimate fisheries components that may be missing from official reported data (Fig. 5). According to these reconstructions, global catch between 1950 and 2010 was 50 percent higher than data as reported by the FAO, and catch is declining more rapidly than reported since the global peak in 1996.[7]

> **As shown in Figure 5, the Sea Around Us actually shows an increased proportion of stocks undergoing rebuilding, potentially pointing to rebuilding taking place in North American and European fisheries.**

Proportion of capture from stocks by stock status | FIG. 5



Proportion of stocks by stock status



Source: Sea Around Us, 2016.

Global fisheries trends

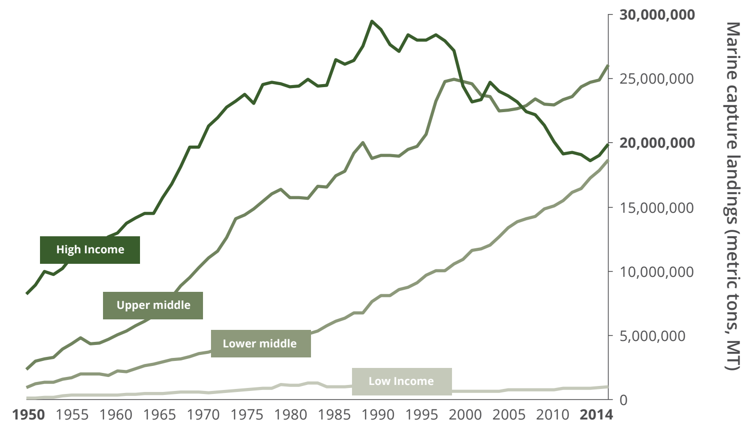
While wild capture landings have been nearly flat since the late 1980s, there has been a major redistribution of catch. Total landings in high-income countries (primarily in North America and Europe) have declined by a third, while landings in upper-middle-income countries (e.g., China, Peru, Russia) and lower-middle-income countries (primarily in Asia) continue to increase (Fig. 6).

Wild capture landings in Asia, mainly fueled by Chinese fleets through the mid-2000s and increasingly by countries such as Indonesia and Vietnam, have steadily increased since the 1950s and now exceed production in the rest of the world combined (Fig. 7).[8] Catch from China alone often surpasses the catches of the next three largest fishing countries combined.[9]

Fishing effort has increased at least fourfold over the past four decades, with a significant increase in fishers in low- and middle-income countries and a decrease in most industrial economies. Substantially more boats and fishers on the water—coupled with developments in fishing technology (particularly fishing gear and fish-finding devices)—have combined to yield an increase in fishing effort and a decline in productivity. As shown in Figure 8, the estimated catch per fisher has declined by more than 50 percent, from just less than 5 tons annually in 1970 to only 2.3 tons in 2012, meaning fishers must "fish harder to catch fewer fish."[10]

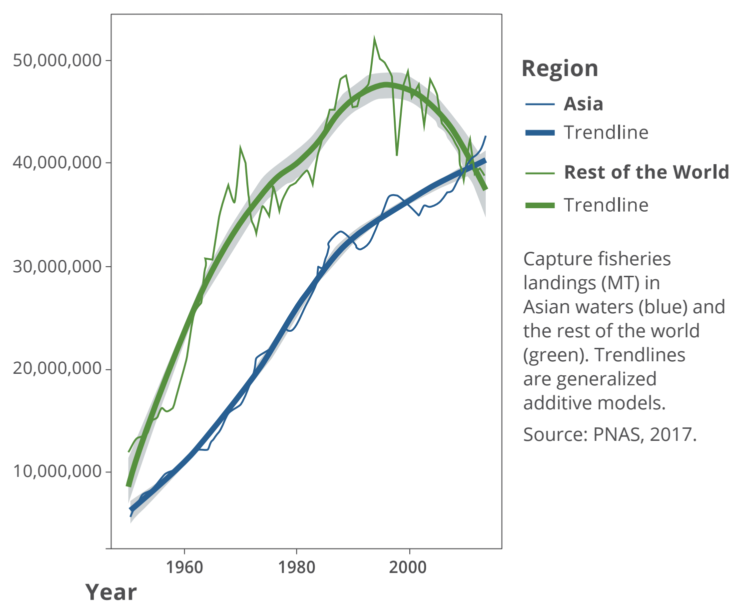
Global landings: By income class, excluding small pelagics | FIG. 6

Global capture by World Bank income class



Source: FAO FishStatJ, 2016.

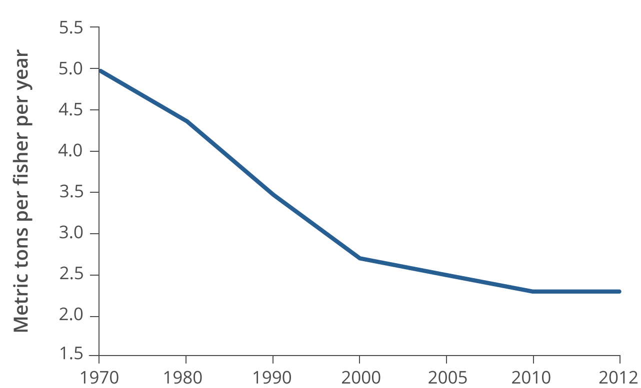
Capture fisheries landings: Asia compared to rest of world | FIG. 7



Capture fisheries landings (MT) in Asian waters (blue) and the rest of the world (green). Trendlines are generalized additive models.

Source: PNAS, 2017.

Average catch per fisher per year | FIG. 8



Source: PNAS, 2017.

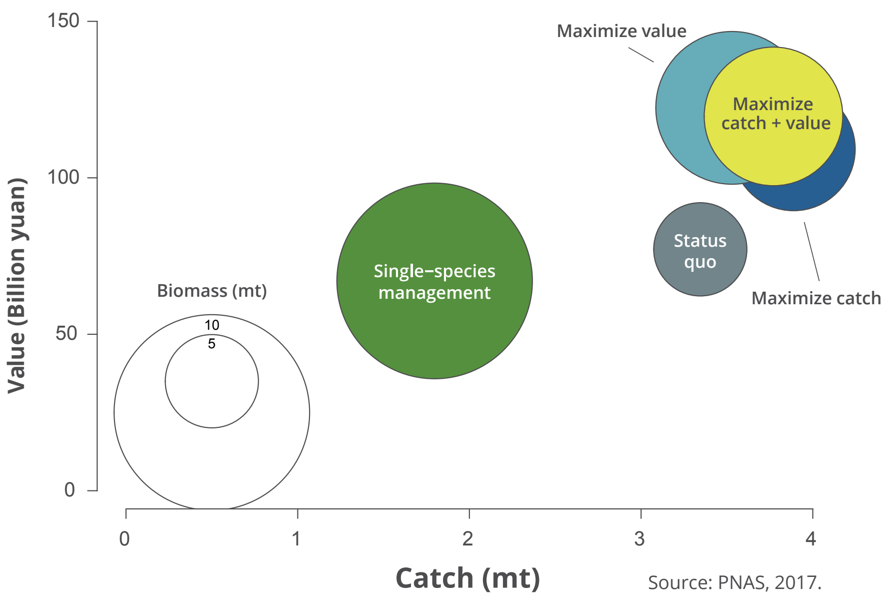
Recent research suggests that the sustained and high productivity in Asian fisheries is driven at least partly by speciation, meaning that the removal of larger predatory fish has allowed increases in the production of smaller fish.[11] While intense, indiscriminate fishing can impact biodiversity negatively, the high volume of catches in China suggests these practices may increase productivity through trophic cascades.

In other fisheries management systems around the world, particularly in North America and Europe, there has been a push for single-species management, in which all species are individually managed to optimize the catch of commercially important stocks. Whereas most developed countries are experiencing lower yields, the experience in China suggests that speciation may be driving production gains in that country.

Reverting to single-species fisheries management would likely result in a loss in long-term catch in a country such as China, where the food web has been condensed through predator removal. As shown in Figure 9, single-species management would increase fish biomass by 109 percent as compared to the status quo scenario but would lead to a tradeoff of decreased catch (-46 percent) and value (-13 percent).[12]

At the global level, "The Sunken Billions Revisited," released in 2017 (Figure 10), estimated that fisheries lose around US $83 billion a year in forgone economic benefits, as compared to what could be generated through more sustainable management. Yet most profits that could be gained from these "sunken billions" relate to lower fishing costs (52 percent) and higher prices of landed fish (33 percent) associated with reducing fleet sizes and making management more economically rational. Only marginal gains (15 percent) would be derived from increasing fish harvest.[13]

Catch, biomass, and value by management strategy | FIG. 9

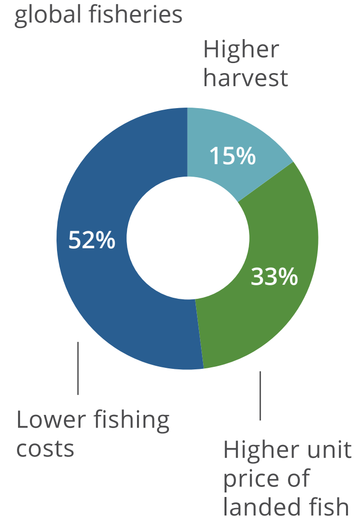


Source: PNAS, 2017.

Ecosystem-wide catch (x axis), biomass (circle size), and value (y axis) by management strategies. Bar plot at the Top displays the selectivity by strategy, color-coded to match the circles representing scenarios within the main figure.

The Sunken Billions, Revisited | FIG. 10

Sources of economic benefits from moving to the optimal sustainable state for global fisheries

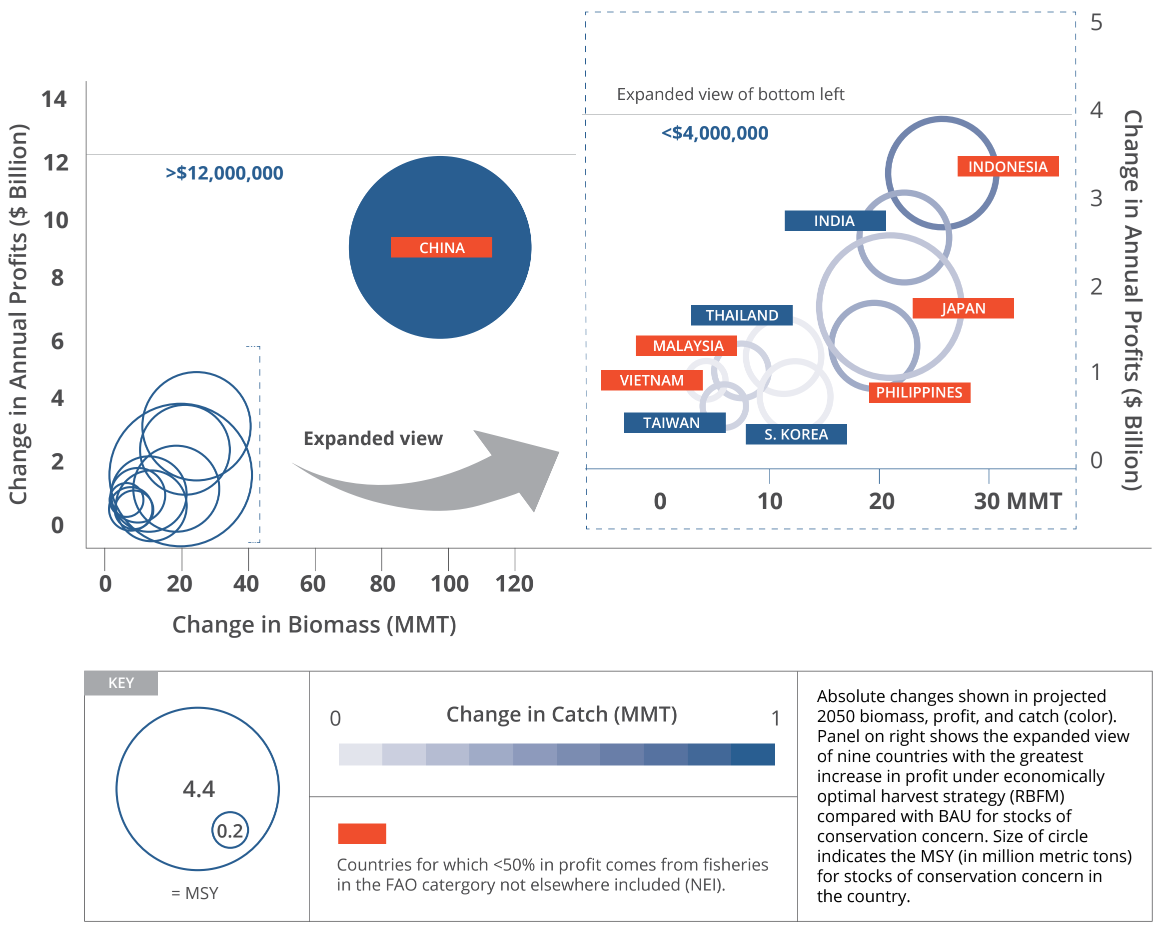


Source: World Bank, 2017.

Fisheries governance and country-level implications

Countries are leaving money on the table as a result of suboptimal fisheries management. While "The Sunken Billions Revisited" suggests that global fisheries lose US $83 billion annually in economic rent due to sub-optimal management, recent research examining country-level implications suggests that fishery reform would drive simultaneous increases in catch, fishery profits, and biomass in nearly every country of the world (Fig. 11).[14] Based on a bioeconomic model that factors in 78 percent of global reported catch, fisheries management reform could generate annual increases in benefits surpassing 16 MMT in catch, US $53 billion in profit, and 619 MMT in biomass (relative to business as usual). A handful of key fishing countries—including China, Indonesia, India, Japan, and the Philippines—have substantial potential for gains across the three dimensions of profits, conservation, and catch.

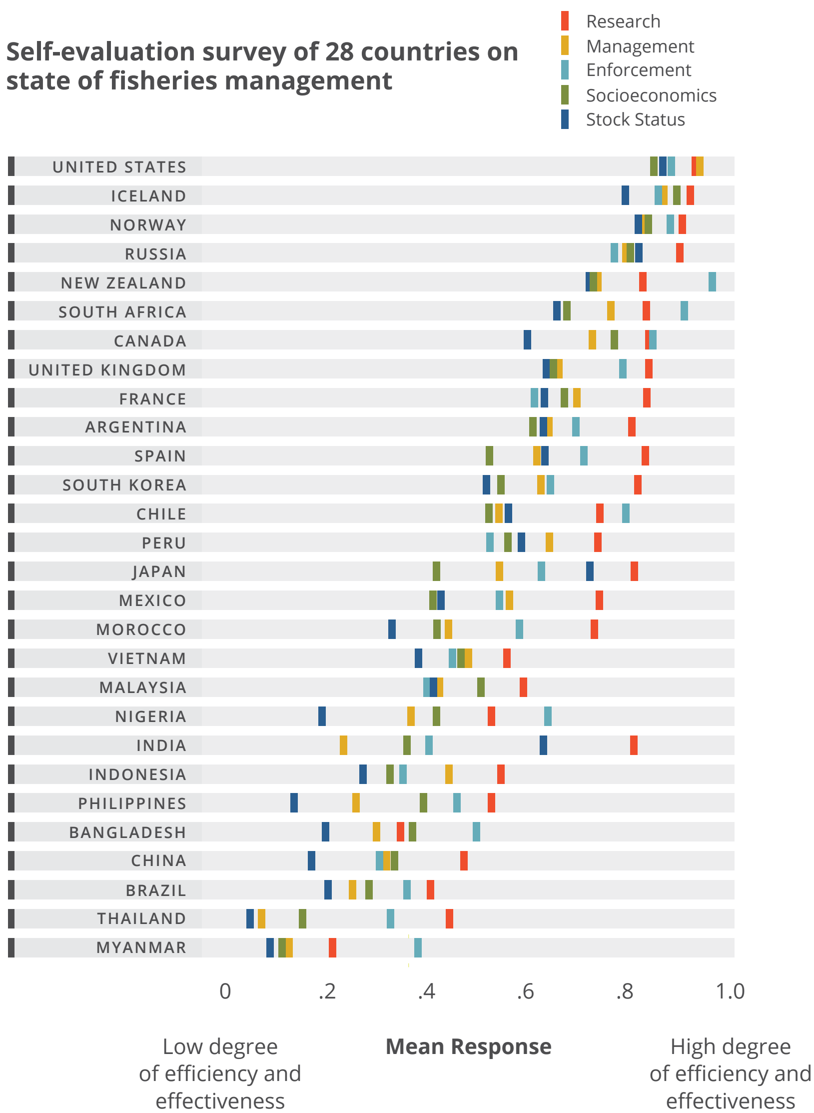
Absolute changes in projected 2050 biomass, profit, and catch | FIG. 11



Source: PNAS, 2016.

Management capacity correlates strongly with fisheries health and varies widely across countries. A recently published Fisheries Management Index (FMI), which used expert surveys to rate the effectiveness of management on a stock-by-stock basis, found substantial variation in management globally. The FMI (Figure 12) found that the three most influential management attributes in determining fisheries health were extensiveness of stock assessments, strength of fishing-pressure limits, and comprehensiveness of enforcement programs.[15] Countries with suboptimal management systems hold the greatest potential for improving long-term stock status outcomes and thus stand to gain the most from improved fisheries management. While good management undeniably comes at a cost, research has found that the benefits of management upgrades outweigh the costs, both at the global level and at least among the top fishing countries of the world.[16]

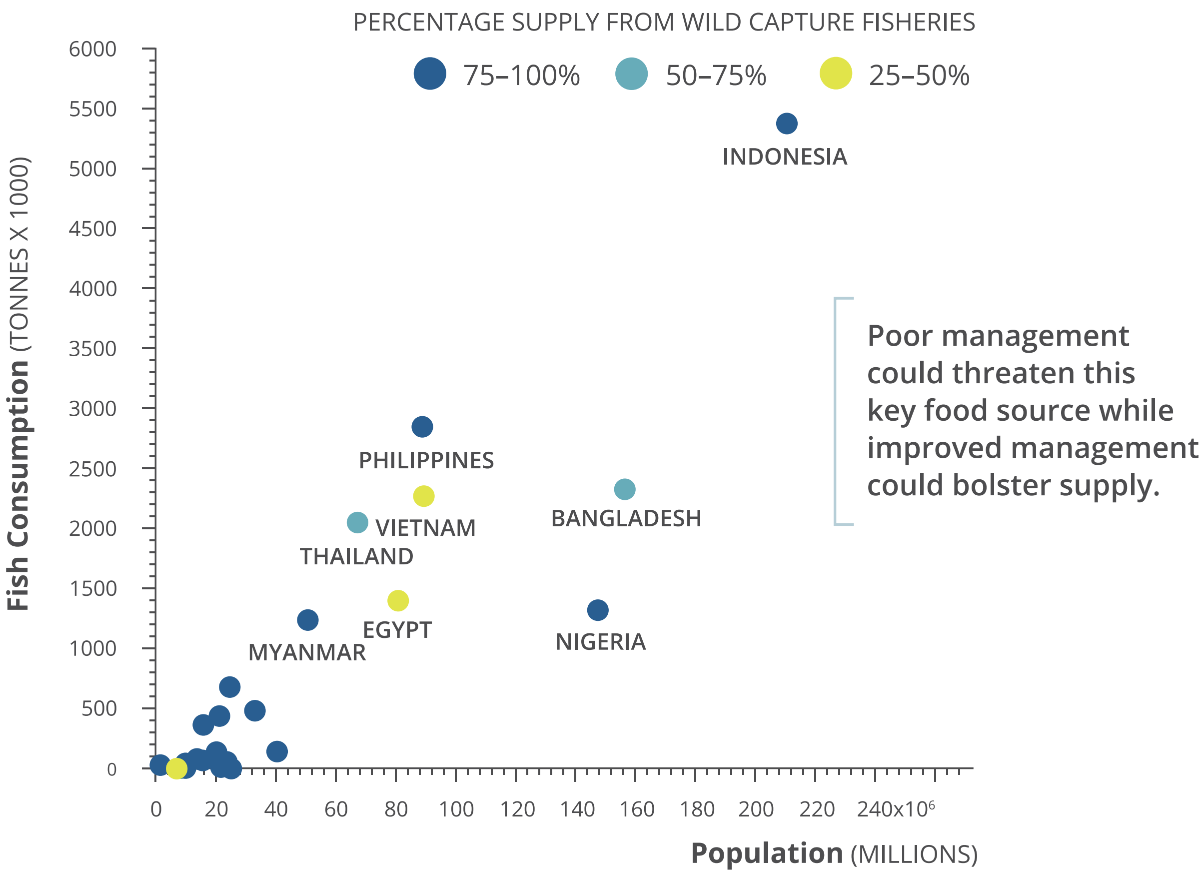
Fisheries Management Index | FIG. 12



Source: PNAS, 2016.

Several countries have high levels of fish consumption and malnutrition and may be at risk of fisheries-related food insecurity. As shown in Figure 13, Indonesia could achieve triple-bottom-line gains through fisheries reform. Its 257 million residents rely strongly on fish, the majority of which is supplied from wild fisheries. Other countries with a compelling rationale for improved fisheries management—including the Philippines, Myanmar, and Nigeria—are also large consumers of wild fish, highlighting important connections with food security.

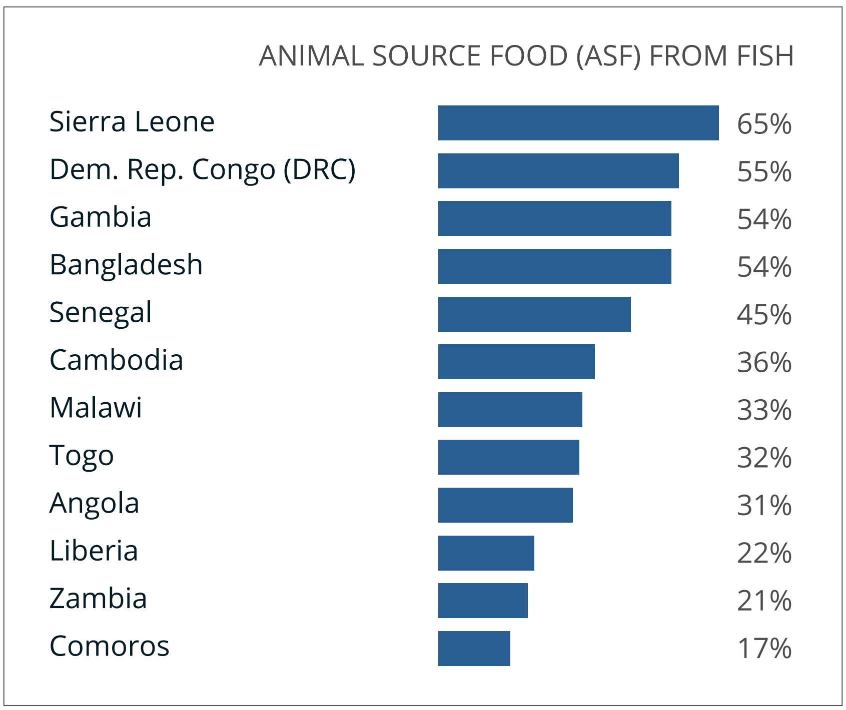
Fish consumption and source of supply (2007) | FIG. 13



Source: WorldFish, 2015.

By overlaying developing countries with high levels of fish consumption and significant levels of undernutrition, it becomes clear that several African countries may be at greatest risk of food insecurity (Fig. 14). The list below shows countries that have a Human Development Index level lower than the 50th percentile, face an undernourishment rate greater than 25 percent (according to FAO Food Balance Sheets), and derive more than five percent of animal source food (ASF) from fish.[18] Aside from Bangladesh, the 12 countries on this list are all located in Africa. This analysis suggests that philanthropic and development initiatives to address food insecurity in countries with high levels of both undernourishment and reliance on wild fisheries should consider directing support toward African nations. This analysis is conducted using national-level figures, so it does not account for the fact that communities in developing countries outside of Africa—in places such as Indonesia, Myanmar, and Vietnam—may also face high rates of undernourishment and high reliance on fish as a key protein source, even if the country as a whole does not meet all conditions for the ranking.

Developing countries with high fish consumption and high undernutrition | FIG. 14



Source: WorldFish, 2015.

Initiatives aimed at addressing food insecurity in undernourished countries with a high reliance on wild fisheries for protein may consider orienting support to African nations.

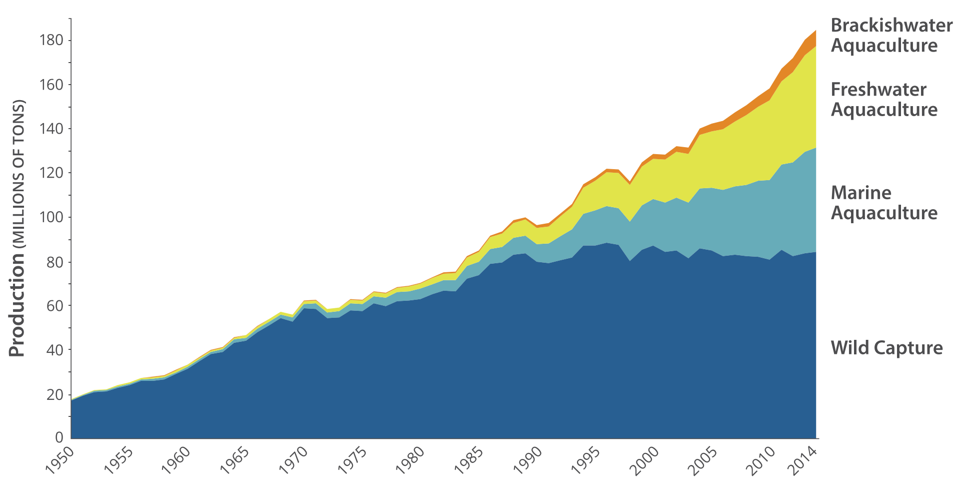
Aquaculture

Production trends

As wild capture production has reached a plateau, aquaculture has become a more significant component of the global seafood landscape and continues to grow (Fig. 15). Global aquaculture production accounted for 44.1 percent of total fish production (including for non-food uses, but excluding farmed seaweed) in 2014, an increase from 31.1 percent in 2004 and roughly 9 percent in 1985.[19]

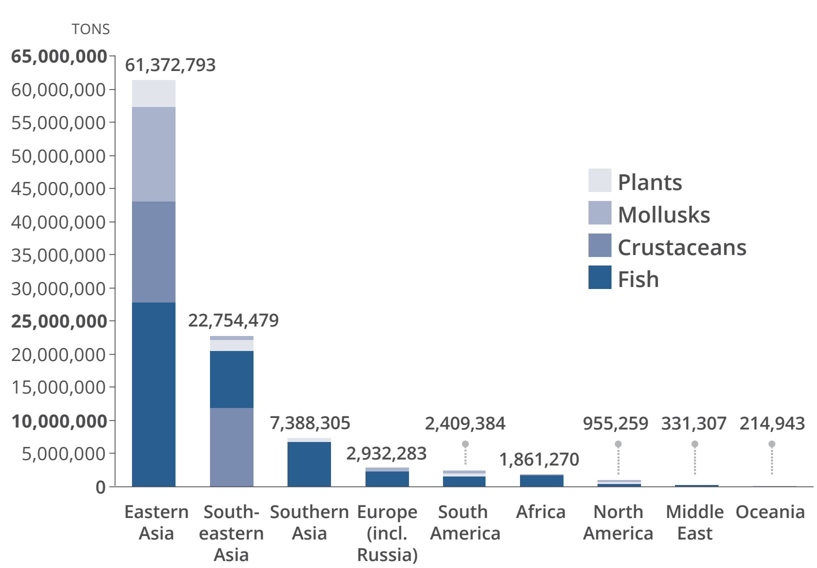
Most of the growth in aquaculture production has come from China, Southeast Asia, and South Asia (Fig. 16). China accounted for more than 60 percent of the global fish production from aquaculture, producing 45.5 million tonnes in 2014. Other key producers include India, Vietnam, Bangladesh, and Egypt. Aquaculture production as a share of total fish production has increased in nearly all continents (aside from a slight decline in Oceania) in recent years.

Wild capture fisheries and aquaculture production (1950-2014) | FIG. 15



Source: FAO SOFIA, 2012.

Total global production by region and type | FIG. 16



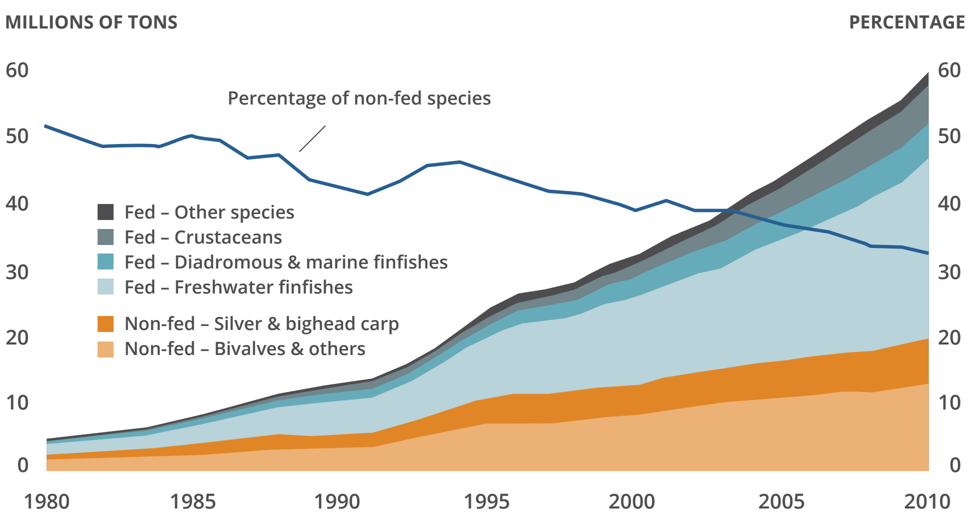
Source: FAO FishStatJ, 2016.

China accounted for more than 60 percent of the global fish production from aquaculture.

The growth in aquaculture production in some parts of the world has resulted in environmental externalities, such as reduced mangrove cover for shrimp aquaculture and high input requirements (such as fishmeal) for fed species. Feed is often regarded as a resource constraint on the aquaculture sector's growth. However, while the percentage of non-fed species has declined over the past decades (in relation to higher-trophic-level species of fish and crustaceans), one-third of all farmed fish—20 million tonnes—is still produced without any feed inputs (Fig. 17).[20]

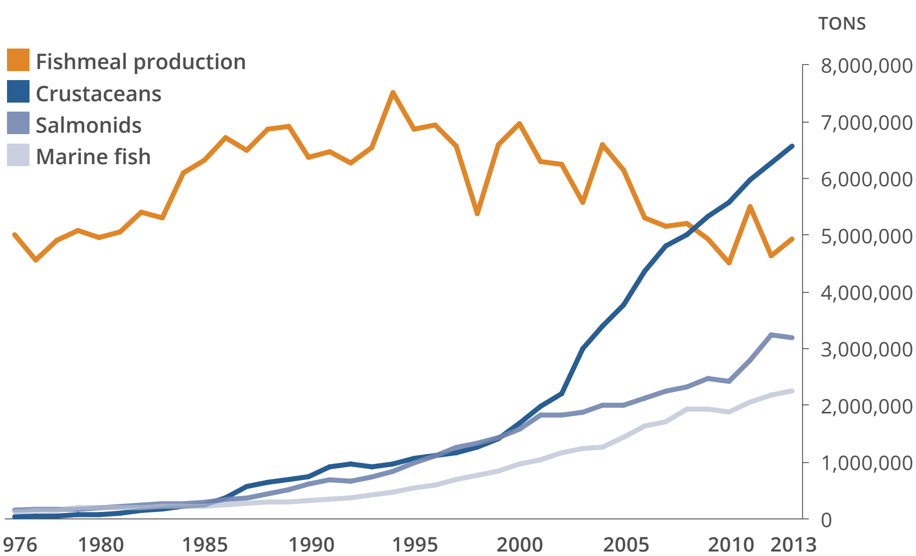
The production efficiency of fed species has steadily improved in recent decades. Between 2000 and 2010, the aquaculture sector realized a 62 percent increase in production while the global supply of fishmeal declined by 12 percent (Fig. 18).[21]

World aquaculture production of non-fed and fed species | FIG. 17



Source: World Bank, 2013.

Total global production of fishmeal and main meal consuming species | FIG. 18



The role of fishmeal and fish oil in aquaculture is expected to decline as the industry develops alternative feeds and efficiencies in feeding practices.

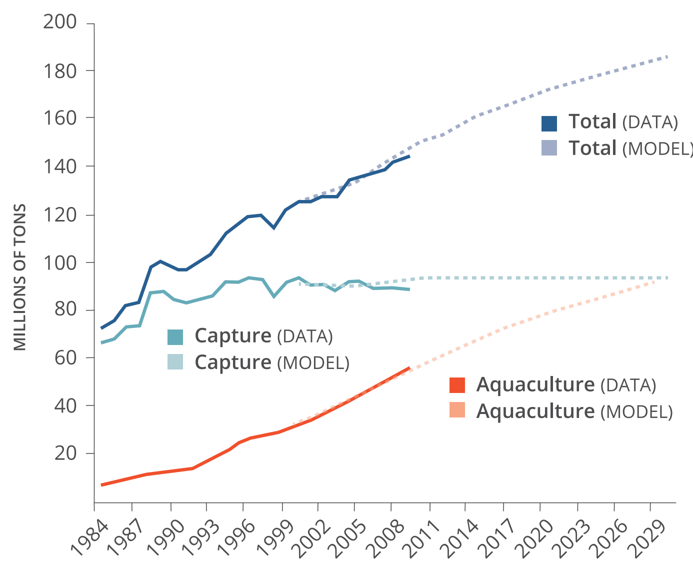
Source: FAO FishStatJ, 2016.

Projected growth in aquaculture production

Available projections suggest continued strong growth in aquaculture production. Although the sector is expected to follow an upward trend, the rate of growth will likely be slower than the sector's peak of 11 percent per year during the 1980s. According to the World Bank's "Fish to 2030" report, aquaculture is projected to account for 62 percent of food fish by 2030.[22] Aquaculture production will likely dominate the global fish supply beyond 2030 (Fig. 19).

The portion of aquaculture products exported to Western markets is relatively small, as many countries (particularly China) retain a large share of aquaculture products for internal consumption (Fig. 20). As shown in Figure 20, carp make up the largest produced species by volume; this production is primarily for domestic consumption in China.

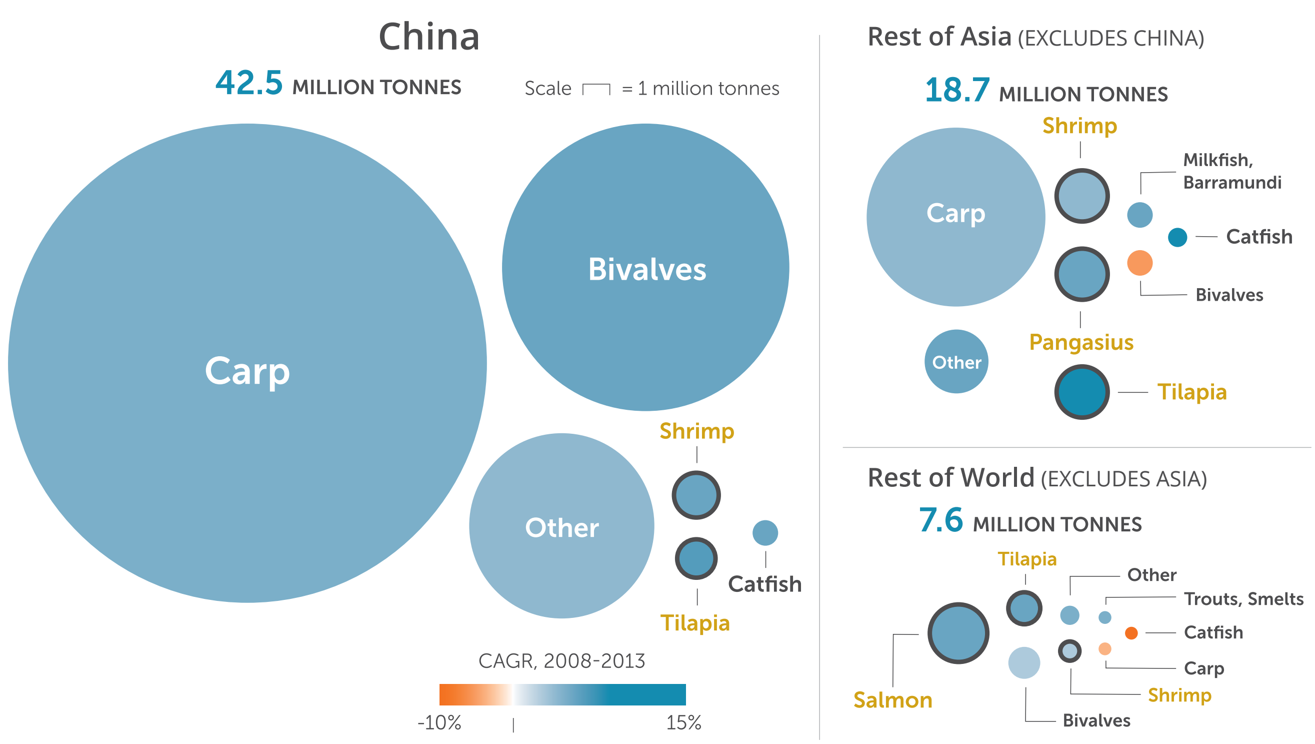
Global Fish Production: Data and Projections, 1984-2030 | FIG. 19



Source: World Bank, 2013.

Global Aquaculture Production and Growth | FIG. 20

Top Species by Aquaculture Production (2013) & Compound Annual Growth Rate (2008–2013)



Black borders and yellow text indicate highly traded commodities exported primarily to Western markets.

Source: FAO 2016, Fishery and Aquaculture Statistics, Global aquaculture production 1950-2013 (FishStatJ); Trade Maps, International Trade Center, 2016, www.tradermap.org.

At current rates, ocean pH may drop another **120 percent by 2100**, creating a more acidic ocean than seen in the past 20 million years. Ocean acidification impacts will cascade throughout the marine food chain in potentially catastrophic ways. Tiny sea creatures called pteropods that feed marine life from krill to killer whales are at risk, in addition to shell-forming animals (including crustaceans and mollusks) which may be unable to build their exterior shell. Acidic seawater may make it more difficult for corals to grow and also endanger phytoplankton, which produce about 60 percent of the oxygen on Earth.

Impacts of climate change

Ocean momentum in a time of change

Dr. Ove Hoegh-Guldberg
Professor and Director
Global Change Institute
University of Queensland, Australia

It is now or never for the ocean. Just as it took time for the first signals of climate change to appear in the ocean, the same gigantic thermal inertia[i] is now bringing us to the brink of no return. For too long, we have ignored the advice of ocean scientists who tell us that our ocean—critically important to all life on our planet—is beginning to change rapidly, dangerously, and irreversibly.

Originally, ocean experts felt that the ocean was so vast and the thermal inertia of water so large that climate change would have few immediate implications for our ocean. This conclusion has been proved wrong. The chemical and physical properties of the ocean are now changing more rapidly than at any other time in the last 65 million years.[1] While deeply troubling, this is a scientific fact and not some sort of "fake news."

Where marine scientists erred was not in getting climate change wrong, but rather in failing to recognize the highly structured nature of the ocean. That is, the ocean is not a well-mixed volume of 1,300,000 km^3 of water. Instead, it is highly structured, with the upper 200 meters or so acting somewhat independently from the rest of the ocean.[2]

The surface of the ocean is also crucially important because extensive ecosystems and human activities crowd this zone. And while we know much about oceans, access to information has been a problem. Whereas our knowledge of terrestrial ecosystems goes back hundreds if not thousands of years, our understanding of the ocean only took off in the 1950s when the invention of SCUBA allowed us regular access to the ocean.

This means that our understanding of the physics, chemistry, and biology of the ocean is far behind our understanding of land-based systems. In fact, just a few years ago, I reviewed the scientific literature on climate change and found that there were 20 times fewer ocean-related studies than papers concerning climate change on land.[3] Even the IPCC, as an international body responsible for assessing climate change science, did not devote a regional chapter to the ocean until its Fifth Assessment Report in 2014.

Fast forward to today, and science is rapidly catching up. Public knowledge and understanding of the role of the ocean in climate change, however, still lag. Many people are surprised, for example, when you tell them that around 93 percent of the extra energy trapped by the enhanced greenhouse effect is absorbed by the upper layers of the ocean. Similarly, people are surprised to hear that carbon dioxide from the burning of fossil fuels is steadily acidifying the surface ocean, at a rate more rapid than at any time since the age of dinosaurs.[4]

[i] Thermal inertia is a measure of how much the temperature of a system will change for a given input of energy. Water has a high thermal inertia because it takes a lot of energy to cause a change in temperature.

One of the clearest signals is that marine life is already changing fundamentally in response to climate change. Professor Elvira Poloczanska, research scientist at CSIRO, recently discovered that in over 80 percent of published studies designed to detect long-term changes in ocean organisms, the direction of change detected was found to be consistent with climate change models (Poloczanska et al 2013). That is, long-term trends in the location of fish stocks, for example, show relocation from lower to higher latitudes given increases in sea surface temperature.[5] Similarly, many other examples revealed that changes in sea temperature and chemistry align with predicted effects on the ocean (e.g., slowing calcification of key types of plankton as ocean warming and acidification has occurred).

Without accelerated intervention, most of these impacts will escalate in the future. For instance, coral reefs are very sensitive to thermal stress and will experience more intense and damaging mass bleaching and mortality events. Even at the lower edge of climate scenarios (essentially, the global emissions goal under the Paris Agreement), sea temperatures will still increasingly exceed the temperature sensitivity of coral reefs, which by 2050 will reduce the extent of Earth's coral reefs to 10 percent of today's extent.[6] This is a similar story to that of other ocean ecosystems, including kelp forests, intertidal communities, and pelagic systems.

The single most important question right now is how we can avoid the catastrophe facing our oceans, and by extension, human communities. The answer, I believe, lies in a simple two-step strategy. The first part of the strategy requires us to think objectively about the world that we are trying to preserve. People often tell me, "Don't tell them all of the bad news; it might depress them!" To the contrary, I believe that we must face up to the reality and science of climate change and admit that we may have already exceeded a point of no return in a large number of cases.

It may come as a surprise for many, but achieving the Paris goals will still mean very tough times ahead, with an increasing frequency of extreme events and increasing stress on Earth's ecosystems.

It may come as a surprise for many, but achieving the Paris goals will still mean very tough times ahead, with an increasing frequency of extreme events and increasing stress on Earth's ecosystems. But there is a silver lining: ocean warming and acidification are expected to stabilize around the middle of the century[ii] if we successfully implement the goals of the Paris Agreement.[iii,7]

Which leads to the second part of this strategy.

Stabilization is generally good news for ocean ecosystems, but only if they can survive to reach this crucial window of opportunity. We must identify those locations where ecosystems have the greatest chance of surviving climate change and do everything we can to reduce the impact of non-climate change stressors, such as pollution, overfishing, and unsustainable coastal management. If we do this, we have a good chance at optimizing the number of coral reefs and other ecosystems that will be present once conditions stabilize to "seed" the recovery of these life-supporting ecosystems.

[ii] See the Representative Concentration Pathways (RCP) 2.6 in the IPCC 5th Assessment Report.

[iii] At the Paris climate conference (COP21) held in December 2015, 195 countries adopted the first-ever universal, legally-binding climate deal. The agreement provides a global action plan to limit global warming to well below 2 degrees Celsius to avoid the dangerous impacts of climate change.

In my opinion, this an “all hands on deck” moment. Solving the problems that face coral reefs and many other essential ecosystems is entirely achievable, but we must approach the problem strategically, immediately, and at a global scale. We need private and public funders to join in a strategic coalition of NGOs, government, scientists, and citizen groups to reverse the decline in ocean health.

This type of strategy does not currently exist for many components of the ocean. Despite many well-intentioned projects, there is no plan that works at global scale for coral reefs, mangroves, rocky shore, seagrass, or other habitats threatened by climate change. That needs to change.

No doubt many will think this type of thinking is ambitious and unrealistic. But faced with the total annihilation of many of the world’s ocean ecosystems, do we have any choice?

Worldwide, fisheries provide **3 billion people** with around **20 percent of their average intake of animal protein**. If global fish catches continue to decline— due to climate impacts, overfishing, weak governance, and pollution—an estimated **845 million** people may experience micronutrient malnutrition. Impacts will be most severe in low-latitude developing nations.

The future of our fisheries under climate change

Dr. William Cheung
Director of Science and Associate Professor
Nippon Foundation–UBC Nereus Program
Institute for the Oceans and Fisheries
The University of British Columbia

The oceans, through marine fisheries, provide important ecosystem services to our society in terms of income, jobs, food, and cultural value. However, the future sustainability of these services is uncertain because of climate change, which is altering ocean conditions. The ocean is getting warmer, more acidic, and less oxygenated. Sea surface temperature is increasing at a rate of 0.12 degrees Celsius per decade, and pH has decreased by 0.1 unit since the 1950s.[1] Changing ocean conditions redistribute fish stocks, reduce fisheries catches, and challenge fisheries management, thus affecting biodiversity and human security. We can still solve these problems, but swift actions to mitigate and adapt to climate change are needed.

Fisheries respond to a changing ocean

Marine organisms' biological performance, particularly that of fish and invertebrates, is sensitive to changing ocean conditions. Marine organisms perform optimally within a specific range of water temperatures. When waters become too hot or cold, performance (such as growth and reproduction) decreases, and ultimately mortality increases. Temperature changes also affect the ocean's primary productivity, the ultimate source of energy to fuel most marine food webs, with observed and projected decreases in large areas of the ocean.

Fish stocks respond to climate change partly through distributional shifts. Range shifts of marine fishes and invertebrates have been most common toward higher latitudes and deeper waters, in general following temperature velocity at rates of tens to hundreds of kilometers per decade.[2] Areas where environmental conditions exceed species' biological limits thus see decreases in abundance, or local extinction in severe cases.

Computer simulation models that analyze all exploited fishes and invertebrates in the world suggest that the rate of range shifts of these marine species would be 65 percent higher under the high-emission scenario relative to the strong carbon mitigation scenario.[3] An intense rate of local extinctions is projected in tropical oceans. In some areas, such as the Indo-Pacific, more than 30 percent of the species may become locally extinct by 2050 because temperature, oxygen, and other conditions will exceed levels that these species have experienced in past centuries.[4] In contrast, the Arctic may see an increase in species richness because of warming, loss of sea ice, and an increase in primary production. However, the Arctic is also a hotspot of ocean acidification, adding uncertainty to the future of polar biodiversity.[5]

Climate change-induced impacts on marine fish stocks are already affecting capture fisheries. From 1970 to 2006, subtropical and higher latitude regions have seen increased catches of warmer water species, while equatorial waters have seen a decrease in the catch of subtropical species.[6] Recruitments of many fish stocks globally have decreased during this period, which is partly attributed to ocean warming.[7]

Challenges to fisheries management and food security

Global fisheries will be substantially impacted by climate change under the business as usual scenario. Recent studies project that global fisheries catch will decrease by 3 million tonnes per degree Celsius of atmospheric surface warming.[8] Concurrently, fisheries will be challenged by changes in species composition through species turnover (species gains and local extinctions because of distribution shifts). As a result, fisheries are projected to lose around US $10 billion in revenue per year globally if greenhouse gas emissions are not mitigated.[9]

Moreover, hundreds of millions of people who previously relied on consuming fish to meet their nutritional needs may face malnutrition.[10] Tropical developing countries (e.g., the Indo-Pacific and West Africa) are especially vulnerable. Impacts there will be severe since these populations are highly dependent on fish for food and livelihoods, and they are relatively less equipped to deal with these impacts. In addition, the Arctic is projected to be highly vulnerable due to a rapid rate of warming and loss of sea ice that causes a high rate of species invasion, while intensive acidification makes impacts on future fisheries in the region still more uncertain.

Climate change-related impacts on fish stocks are challenging fisheries management by disturbing trans-boundary stocks management, reducing accuracy of scientific management advice, reducing effectiveness of management strategies, and enhancing conditions for using illegal fishing methods.

In addition, shifts in stocks are leading to disputes about quota sharing between countries, as seen in the case of Atlantic mackerel fisheries. In the 2000s, thanks in part to the warming North Atlantic, the distribution of Atlantic mackerel shifted poleward, causing greater abundance of Atlantic mackerel in Iceland and the Faroe Islands.[11] In 2010, these two jurisdictions unilaterally increased their catch quota from a total of 27,000 tonnes to 280,000 tonnes per year. This led to a major dispute in the sharing of quota between countries fishing this species in Europe and destabilized the co-management of the species, to the extent that the Marine Stewardship Council withheld its certification of Atlantic mackerel fisheries as sustainable.

The case of cod in the Gulf of Maine is another example of how rapidly warming waters have complicated fisheries management. Waters in the Gulf of Maine—which is at the southern boundary of Atlantic cod distribution—have warmed in the last decade at a rate faster than 99 percent of the global ocean.[12] Empirical evidence suggests that increased water temperatures have reduced recruitment and increased mortality in the region’s Atlantic cod stock, linking cod collapse directly to the rapid warming of ocean waters.[13] Over the past decade, fisheries managers have restricted cod harvesting in the Gulf of Maine, yet even these strict quota limits could not reverse quickly declining cod stocks.

Shift in species distribution may also result in an increase in spatial overlap between targeted and bycatch species, potentially increasing bycatch and discards in fisheries. In developing countries that lack alternative livelihoods, the loss of fisheries catch potential may promote the use of destructive, often illegal, fishing methods, leading to ecosystem damage and loss of biodiversity.[14]

The way forward

Solutions to this grand challenge are still available and within reach. The world has set the goal to limit global warming to 1.5 degrees Celsius above preindustrial levels through the Paris Agreement. Achieving this goal would largely reduce the impacts of climate change on global fisheries to a level that fishers, business, and managers can adapt to.

Adaptation includes protecting and restoring ecosystems, fish stocks, and habitats; reducing fishing capacity and pollution; diversifying livelihoods; and promoting social security and better communication of information about future changes. Ecosystems that are well protected from human stressors are less sensitive to ocean warming, particularly in the case of biogenic habitats such as kelp and corals. Maintaining a diversity of fish populations also helps species to adapt to climate change. Fishers with varied livelihood options could be less dependent on resources that may dwindle under climate change. Better communication of scientific knowledge about climate change and fisheries would also facilitate adaptation to potential changes and impacts.

We are now at a crossroads for seafood sustainability. We are changing our oceans in unprecedented ways. Good science and collaborative efforts to develop and support solutions are necessary to ensure a future of sustainable fisheries.

- **Better communication of scientific knowledge about climate change and fisheries would also facilitate adaptation to potential changes and impacts.**

The impacts of climate change on the marine environment

The ocean plays a pivotal, often underappreciated, role as a climate regulator. Since the 1970s, the global ocean has absorbed most of the additional heat trapped through global warming.[1] It has already captured over a quarter of anthropogenic carbon dioxide (CO_2) emissions since 1750 and will ultimately store the large majority of that carbon.[2] Through these functions, the ocean buffers the earth's atmosphere from the impacts of climate change. Yet these climate-regulating services come at a cost, as the physics and chemistry of the ocean are changing at a faster rate than any other time in recent history. Changes in global ocean properties—in particular, sea-surface temperature, acidity, and oxygen levels—are impacting marine ecology, from the organism to the ecosystem level. The impacts of climate change interact with other human-induced stressors, such as overfishing, habitat destruction, and pollution, intensifying the pressure on marine ecosystems.

This chapter explores the climate-induced environmental changes that the ocean is undergoing; the key marine ecosystems at risk, particularly the Arctic and coral reefs; the projected impacts of climate change on fisheries production and management; and the future implications for the ocean based on the current global climate agreement.

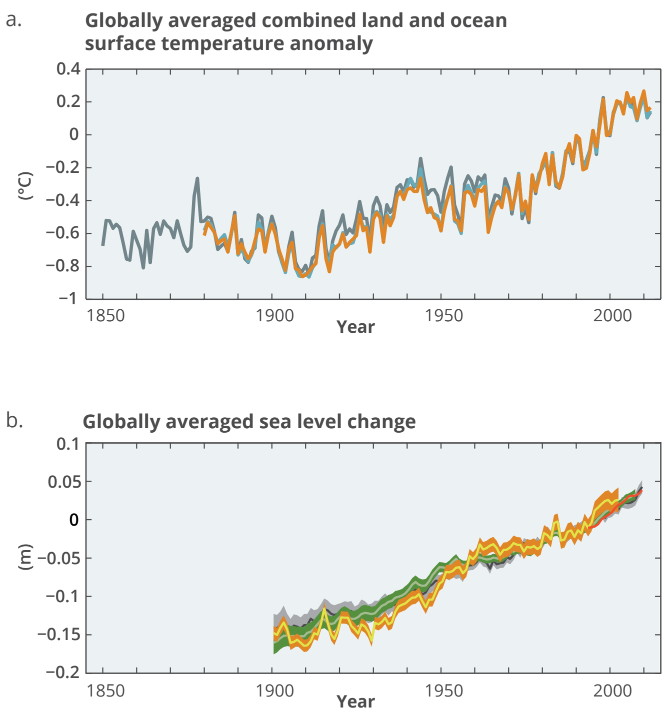
Climate change and the changing physics and chemistry of the ocean

The most recent IPCC Synthesis Report, released in 2015, is direct about the observed changes in the climate system: "Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen."[3]

As shown in Figure 1, there is a long time-series documenting the connection between greenhouse gas (GHG) emissions, average GHG concentrations, surface temperature, and sea level. Cumulatively, humanity has emitted close to 2,000 gigatons of CO_2 to date and continues to emit around 40 Gt CO_2 per year. As a result, atmospheric CO_2 levels have increased from 278 parts per million (ppm) in the industrial period to over 400 ppm today.[4] Higher CO_2 concentrations, along with other GHGs such as methane and nitrous oxide, are inexorably driving increases in global surface temperatures, which reached new records in 2014, 2015, and 2016. Climate change has also produced more extreme weather events, such as droughts and floods, an intensified hydrological cycle, and melting of snow, glaciers, and ice sheets.[5,6]

It is easy to forget that Earth is fundamentally a water planet: the ocean's is nearly 270 times larger than the atmosphere, and the thermodynamic and chemical dimensions of climate change are playing out in profound ways under the surface of the water. To start, approximately 93 percent of the excess heat trapped by GHG emissions has been absorbed by the ocean since the 1970s.[7] Melting ice and warming land account for most of the remainder, while the atmosphere itself has stored less than 1 percent of that excess heat (Fig. 2). Within the ocean, heat absorption has occured disproportionately in the upper layers, given the stratification of the ocean's structure. As shown in Figure 2, the upper ocean (above 700 meters, shown in light blue) has absorbed most of the warming, while the deep ocean (shown in dark blue) has absorbed the remainder of the ocean's share. Given the slow mixing rate of oceanic waters, the increase in temperature has been most pronounced at the surface. The average temperature of the upper 75 meters of the ocean has increased by roughly 0.11 degrees Celsius since 1971.[8]

Observations and other indicators of a changing global climate system | FIG. 1



Observations:

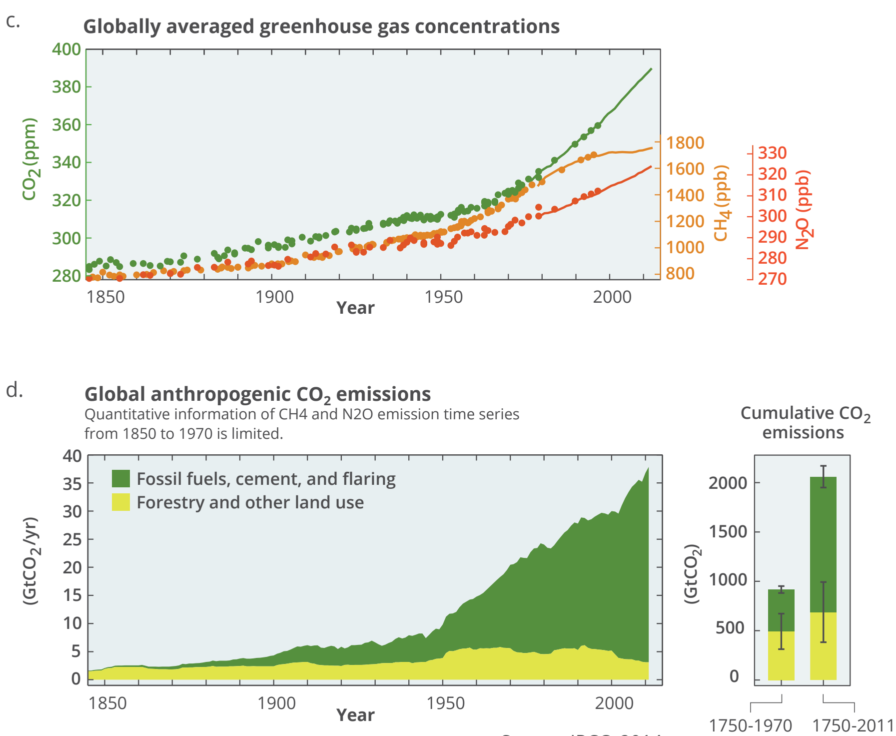
a. Annually and globally averaged combined land and ocean surface temperatures anomalies relative to the average over the period 1986 to 2005 in the longest-running dataset. Colors indicate different data sets.

b. Annually and globally averaged sea level change relative to the average over the period 1986 to 2005 in the longest-running dataset. Colors indicate different data sets.

c. Atmospheric concentrations of the greenhouse gases carbon dioxide (green), methane (orange), nitrous oxide (red) determined from ice core data (dots) and from direct atmospheric measurements (lines).

Indicators:

d. Global anthropogenic carbon dioxide emissions from forestry and other land use as well as burning of fossil fuel, cement production, and flaring. Cumulative emissions of CO_2 and their uncertainties are shown as bars and whiskers on the right-hand side.



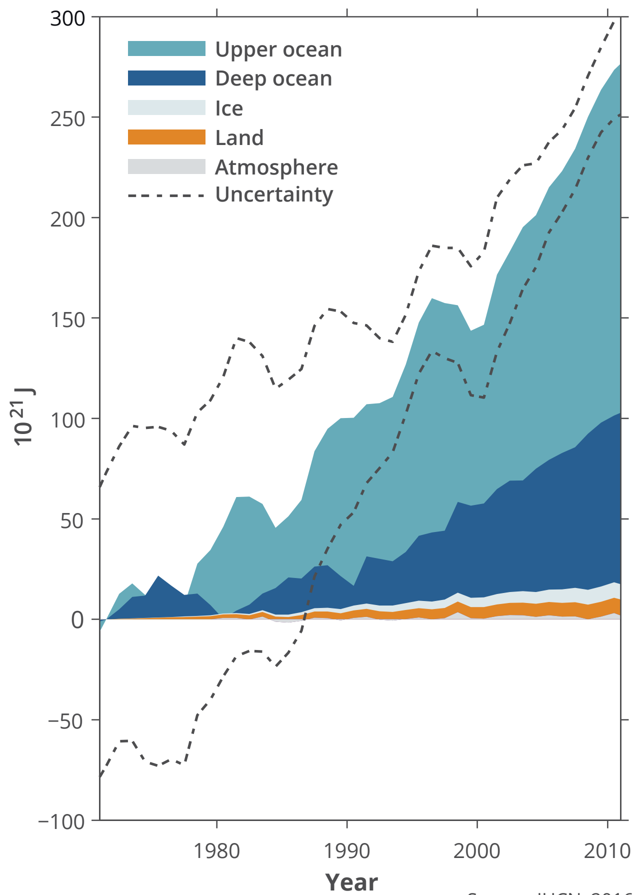
Source: IPCC, 2014.

In tandem with temperature change, the ocean is also beginning to experience fundamental changes in a variety of environmental conditions, including salinity, pH, oxygen levels, and circulation. Many of these changes are occurring at a scale unprecedented in at least the last several thousand years.

For example, the increased uptake of carbon dioxide in the ocean is acidifying surface waters. Surface ocean pH has decreased by 0.1 pH units since the industrial period, resulting in a 30 percent increase in ocean acidity in the past 250 years. Ocean acidification creates difficult environmental conditions for some marine life, especially organisms that form calcium-based shells (including corals, crustaceans, and shellfish).

Ocean acidification has occurred in tandem with other changes, such as decreased oxygen levels in coastal waters and in the open ocean. Oxygen minimum zones are expanding particularly in the tropical Pacific, Atlantic, and Indian Oceans for a combination of reasons, including increased SST, which causes the ocean to lose its ability to hold oxygen. The IPCC predicts that oxygen levels in the ocean will decrease by 3-6 percent during the 21st century in response to surface warming, with impacts felt acutely in hypoxic and suboxic areas, where oxygen is already a limiting factor.[9] Declines in oxygen levels will have wide ecosystem-level impacts, as certain fish species and mollusks are unable to survive with reduced oxygen.

Energy accumulation by the Earth's climate system | FIG. 2



Source: IUCN, 2016.

Energy accumulation by earth's climate system. Estimates are shown relative to 1971. Dashed lines indicate 90% confidence intervals for all variable combined.

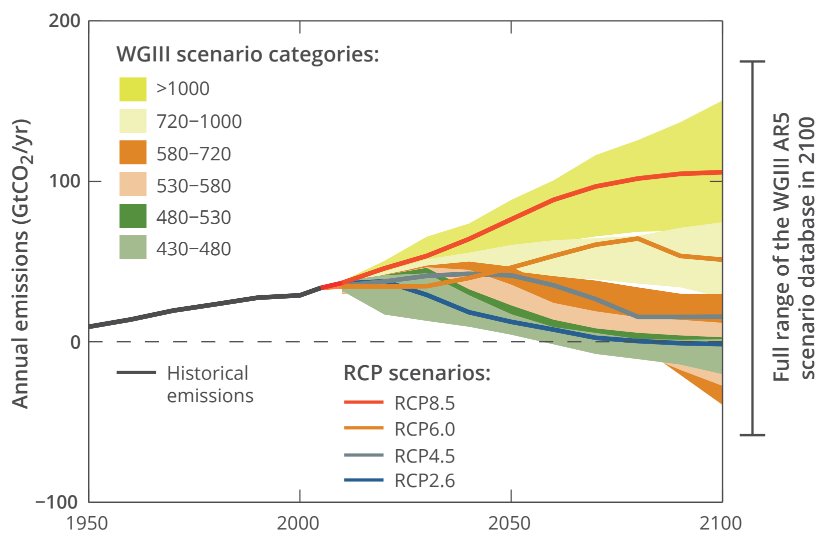
Ocean warming and continental ice melting have led to sea level rise: during the period 1901 to 2010, global mean sea level rose by roughly 1.7 millimeters per year, with a rate which was almost twice the long-term average during 1993 to 2010.[10] Sea level rise has major implications for estuaries and wetlands, particularly where they abut human development.

Future climate and ocean conditions will be determined by how aggressively humanity pursues mitigation options. The IPCC uses Representative Concentration Pathways (RCPs) to describe four different 21st century pathways of GHG emissions (Fig. 3). The RCPs include a stringent mitigation scenario (RCP2.6), two intermediate scenarios (RCP4.5 and RCP6.0), and a high emissions scenario (RCP8.5). The average temperature projected across climate models under RCP2.6 by 2100 is around 2 degrees Celsius, which is consistent with the global goal set forth in the Paris Agreement.

Depending on which climate scenario unfolds:

- Sea surface temperature (SST) is projected to increase by 1.13 degrees Celsius under a stringent emissions scenario to 3.15 degrees Celsius under a high emissions scenario by by 2100, relative to 1870.[11] The strongest SST warming is projected to occur in tropical and Northern Hemisphere subtropical regions.
- The ocean will become increasingly acidic, which will make it difficult for some marine life to survive. Under high emissions scenarios, sea surface pH will decrease by 0.41 units by 2100, a rate that is unprecedented over the past several million years.[12] Under a stringent emissions scenario, pH will decrease by 0.15 units by 2100.[13]
- Global mean sea level rise will continue to rise during the 21st century (Fig. 4). The rise will likely be in the range of 0.26-0.55 meters for RCP2.6, and 0.45-0.82 meters for RCP8.5, during the period 2081-2100 (relative to 1986-2005).[14] The IPCC projects that sea level rise will vary across regions, with roughly 70 percent of coastlines worldwide expected to experience a sea level change within 20 percent (plus or minus) of the global mean.[15]

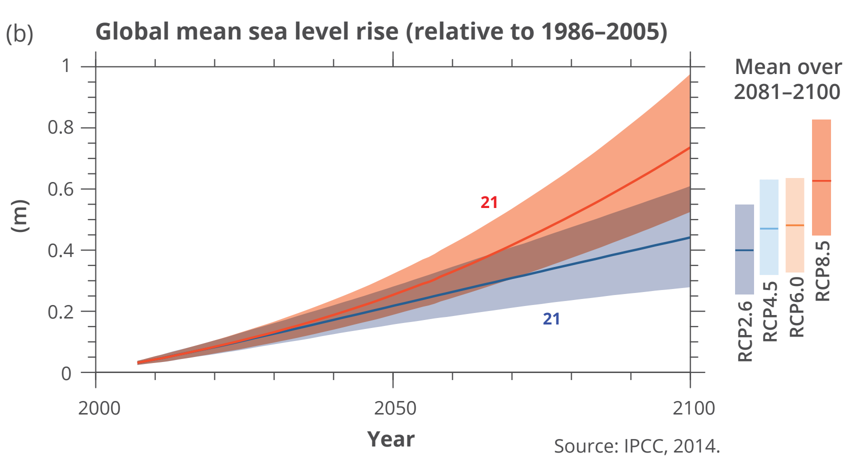
Emissions of carbon dioxide (CO_2) | FIG. 3



Emissions of carbon dioxide (CO_2) in the Representative Concentration Pathways (RCPs) (lines) and the associated scenario categories used in Working Group III (WGIII), colored areas shown in 5%-95% range. The WGIII scenario categories summarize the wide range of emission scenarios published in the scientific literature and are defined on the basis of CO_2-equivalent concentration levels (in ppm) in 2100.

Source: IPCC, 2014.

Global mean sea level rise | FIG. 4



Global mean sea level rise from 2006 to 2100 as determined by multi-model simulations. Time series of projections and a measure of uncertainty (shading) are shown for scenarios RCP2.6 (blue) and RCP8.5 (red). The mean and associated uncertainties averaged over 2081–2100 are given for all RCP scenarios as colored vertical bars at the right-hand side of each panel. The number of Coupled Model Intercomparison Project Phase 5 (CMIP5) models used to calculate the multi-model mean is indicated.

Source: IPCC, 2014.

Ecosystems at risk

The scale and pace of climate change is impacting some marine ecosystems in profound and immediate ways. Observed changes are fastest and most severe in ecosystems such as the Arctic and tropical coral reefs which are already being pushed toward critical tipping points.[16]

The Arctic's climate shifts to a new state

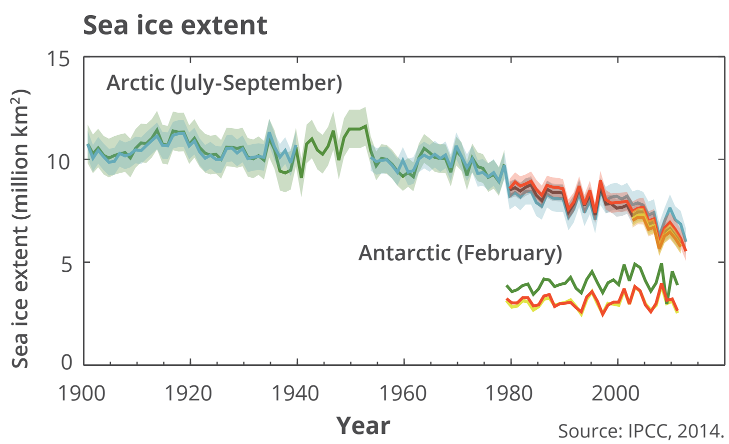
Arctic surface temperatures have been warming approximately twice as fast as the global average for the past fifty years. This warming has led to dramatic reductions in sea ice thickness and extent (Fig. 5), accelerated melting of glaciers, and increases in permafrost warming.[17]

The pace of these changes is concerning for many reasons, particularly given the Arctic's role in regulating the global climate system. First, melting sea ice in the Arctic could add an influx of freshwater to seawater at high latitudes, including in the North Atlantic, which could Interference with this ocean circulation pattern known as the thermohaline circulation. Interference with this circulation pattern could lead to considerable changes, such as impacts to climate patterns in Europe. Second, meltwater from Arctic glaciers and the Greenland ice sheet are a leading contributor to global sea rise. Third, the Arctic is a simultaneous source and sink for GHGs. Fluctuations in the storage and release of carbon dioxide and methane in the Arctic could impact the global climate writ large. The loss of reflective sea ice will also decrease Earth's albedo, another positive feedback loop.

The most recent Snow, Water, Ice and Permafrost (SWIPA) assessment, released in April 2017, revealed several new findings about climate change impacts in the Arctic, with three points emerging as particular concerns:[18]

- ***As early as the 2030s, the Arctic Ocean could be largely free of sea ice in summer.*** Aside from the most northern regions of the Arctic Ocean, the average number of days with sea ice cover in the Arctic declined at a rate of 10-20 days per decade during 1979-2013. The rate of decline is unprecedented in some areas. An ice-free Arctic could provide conditions for the expansion of commercial activities in the region, including through new shipping routes and increased oil and gas development, further exposing an already fragile environment.

Arctic (July to September average) and Antarctic (February) sea ice extent | FIG. 5



Source: IPCC, 2014.

- ***Global sea level rise may occur faster than previously thought,*** given new knowledge on additional melt processes impacting Arctic and Antarctic glaciers, ice caps, and ice sheets. Melting Arctic land ice accounted for more than one-third of global sea level rise during the period 2004-2010. Greenland's massive ice sheet has been the largest driver of sea level rise: roughly 70 percent of the Arctic's contribution to sea level rise has come from Greenland. If emissions continue according to current trends (RCP8.5), the Arctic Monitoring and Assessment Program (AMAP) projects that 0.74 meters would be the low-end projection of global sea level rise by 2100—roughly 0.22 meters (nearly one foot) higher than the current IPCC estimate referenced earlier.
- ***The impacts of changes in the Arctic reach far beyond the region, as observed through its influence not only in global climate regulation but on weather patterns throughout the world.*** New research links the loss of land and sea ice in the Arctic to changes in Northern Hemisphere floods, storm tracks, and winter weather patterns. Arctic changes even appear to influence the timing and intensity of the Southeast Asian monsoon.

While defining features such as sea ice decline are among the visible evidence of the effects of climate change in the Arctic, what occurs below the sea ice may also change dramatically. While other features of the Arctic, including sea ice extent and temperature fluxes, are well studied, scientists know comparatively little about the biological response of animals in the region and potential impacts to the food chain. For one, reduced sea ice may impact migration patterns and lead to increased predation in key aggregation areas. Though the Arctic may become a refuge for northern migrating marine life, ecosystem-level impacts, including whether the food chain can support such shifts, remain unknown.

> **"We can't really say the Arctic is going to change, and we can't really say the Arctic is changing. The Arctic has changed. It is different than it was even 10 or 15 years ago. It's a profoundly different place."**
>
> —Walt Meier, research scientist at NASA Goddard Space Flight Center

Given the Arctic's role in climate regulation, sea level rise, and global commerce, changes in the region extend far south of the Arctic Circle.[19] In the coming years, the Arctic is likely to face multiple drivers of change that will impact livelihoods and ecosystems. Beyond climate change, other stressors—including fishing, oil and gas activities, mining, shipping, tourism, and pollutants—are likely to interact with each other, resulting in wide-ranging consequences.

One economic analysis estimated that the cumulative cost of these global changes will be on the order of US $43 trillion (varying according to the rate of GHG emissions) during the period 2010-2100. More aggressive reductions in anthropogenic GHG emissions could reduce the costs to around US $6 trillion.[20]

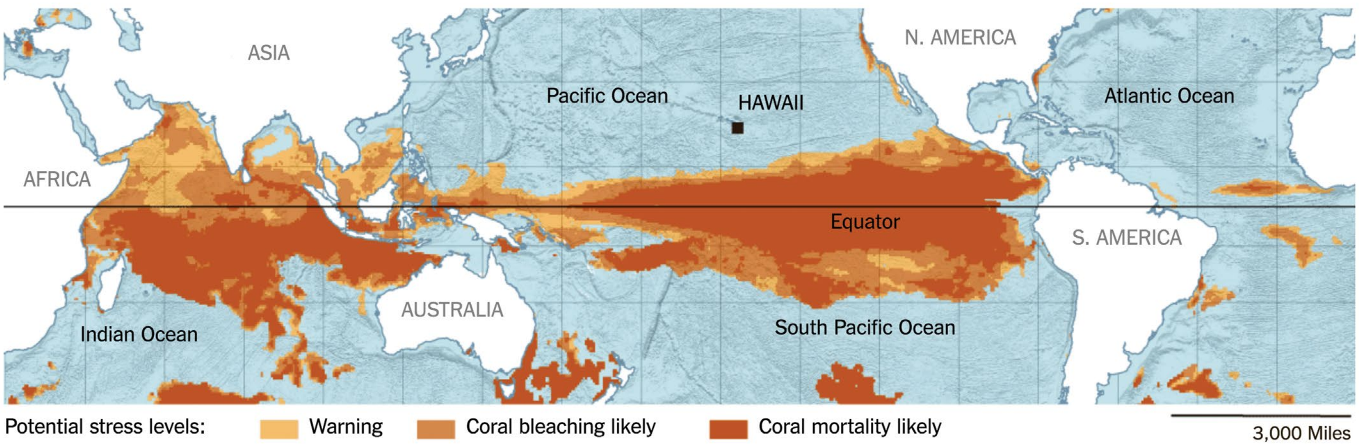
Some of the changes impacting the Arctic will be practically irreversible, and the Arctic may become a fundamentally different place in the near future. Implementing the goals of the Paris Agreement would help limit the extent of changes in the Arctic, including by stabilizing temperature, snow cover and permafrost losses; and reducing global sea level rise.

Coral reefs in decline

Coral reefs are highly sensitive to thermal stress, and sea temperatures (particularly in the tropics) are exceeding the temperature sensitivity threshold of many coral reef systems. An estimated 30 to 60 percent of coral reefs have died since preindustrial times, with projections that 90 percent will disappear by 2050 at the current rate of temperature rise.[21] Temperature stress will only be compounded by acidification, as well as fishing pressure and pollution.

The decline of coral reefs has significant implications for food security and biodiversity. Despite covering less than 0.1 percent of sea floor area, coral reefs serve as incubators for roughly 25 percent of all marine fish species. They support fish stocks that provide food for one billion people, and an estimated 30 million small-scale fishers depend on coral reefs for their livelihoods.[22] In terms of their value for food and livelihoods, coral reefs are estimated to generate US $300-400 billion annually through food, tourism, and medicinal contributions.[23]

Reports of damaged or dying coral reefs | FIG. 6

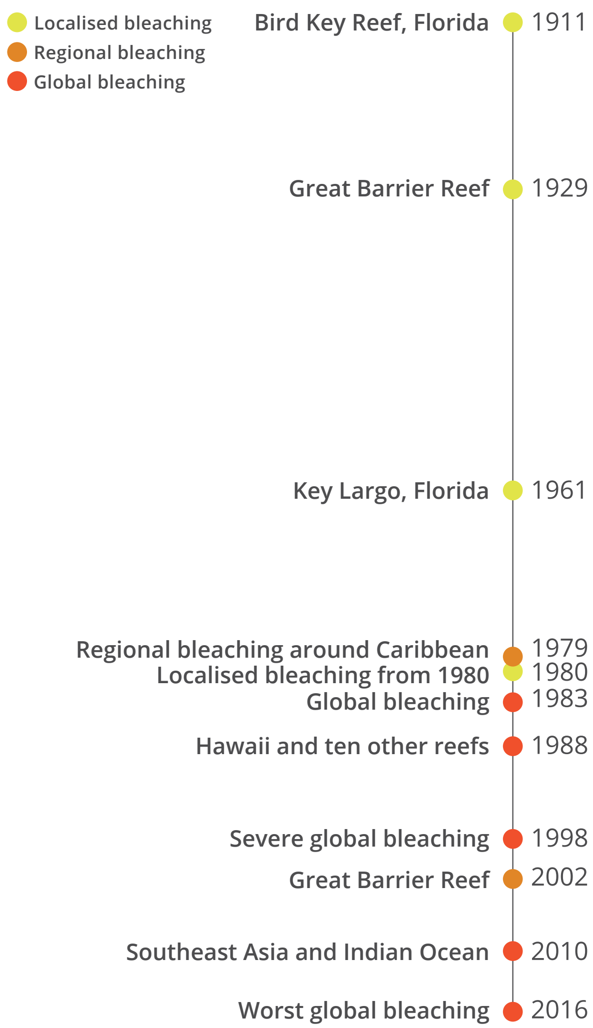


Source: NOAA/GEBCO.

Changing ocean conditions, particularly increased sea surface temperature, deoxygenation, and acidification, are most pronounced in tropical regions, where large-scale coral bleaching events have been observed (Fig. 6). The rate of warming in coral reef areas has increased from approximately 0.04 degrees Celsius per decade over the past century to 0.2 degrees Celsius per decade during the 1985-2012 period.[24] As warming increased over these three decades, bleaching events also increased three-fold, with more frequent and intense bleaching events due to prolonged exposure to temperatures that exceed the sensitivity threshold of reef systems (Fig. 7).

Bleaching events can result in reduced reproduction of coral, diminished habitat for fish and other fauna, decreased biodiversity, coral death, and even local extinction. Following increases in temperature and acute thermal stress events, the condition of corals weakens, making the coral reef ecosystems vulnerable to slowed growth and disease outbreaks. The Third Global Coral Bleaching Event began in 2014 and continues to be ongoing as of May 2017, making it the longest, most widespread, and most damaging event on record. This event has affected more reefs than any previous global bleaching event, with pronounced impacts in specific geographies including the Great Barrier Reef, Kiribati, and Jarvis Island.

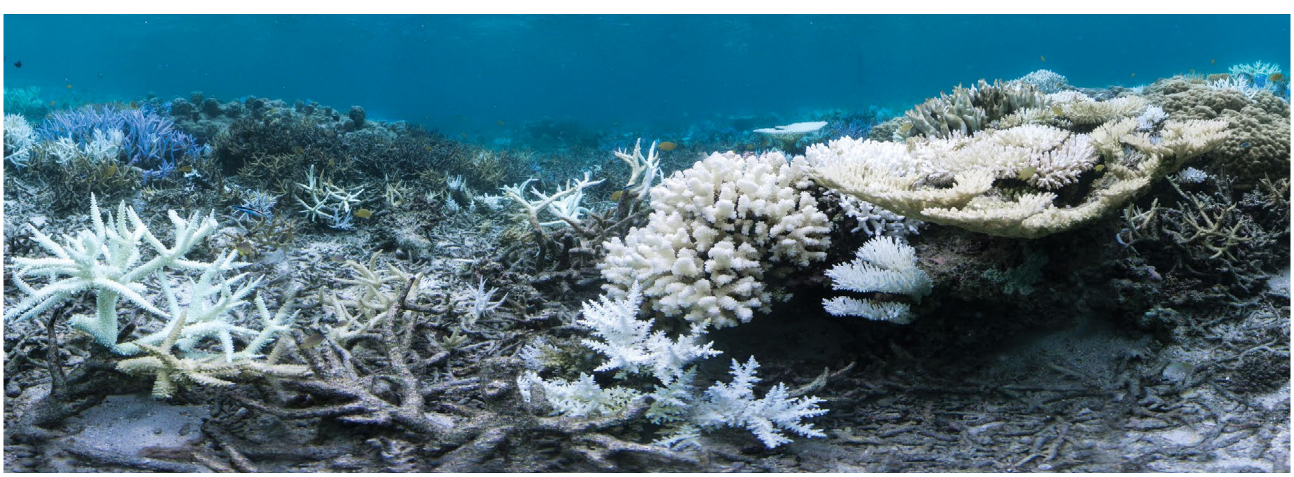
Key coral bleaching events | FIG. 7



Sources: Berkelmans et al (2004), Goreau and Hayes (1994), Williams and Bunkley-Williams (1990)

Ocean acidification is further diminishing the ability of corals to survive changing ocean conditions. The proportion of reefs that can survive and grow in ocean chemistry conditions has decreased from 98 percent in pre-industrial times (ca. 1780) to 38 percent (ca. 2006), with continued decreases projected. More acidic seawater increases reef erosion and reduces the structural integrity of reefs, making them less able to withstand physical damage.

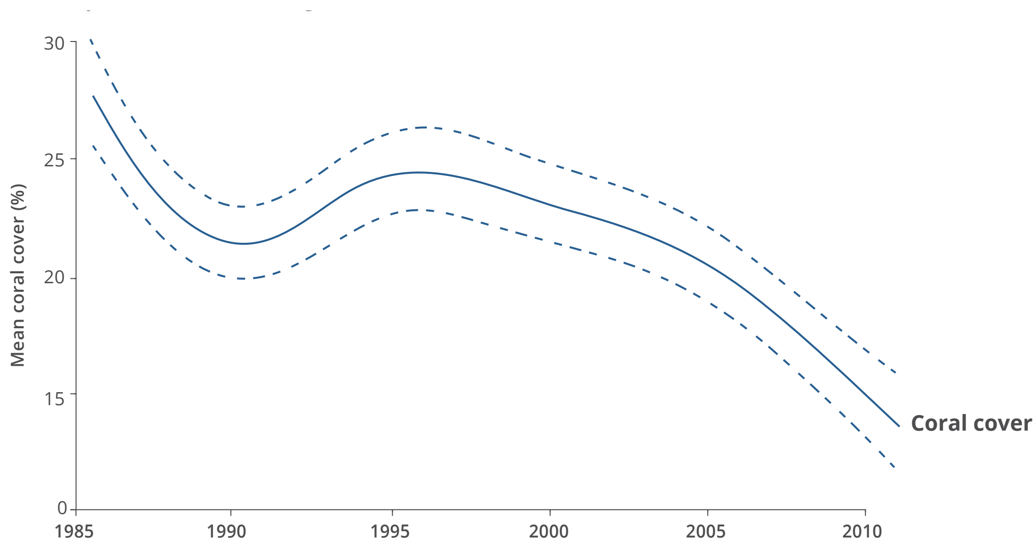
Climate change presents the greatest threat to the future survival of coral reefs, with projections that only 10 percent will survive beyond 2050. Current CO_2 levels already surpass the 320-350 ppm levels needed for healthy coral reefs.[25] To help stave off extinction, a global initiative called "50 Reefs" was launched in February 2017 to scientifically identify 50 reefs which are least vulnerable to climate change and have the greatest likelihood of survival to repopulate other reefs over time. Akin to a "Marshall Plan for coral reefs," the initiative is attempting to shift the focus from critically endangered reefs to those that have the greatest likelihood to survive and seed the repopulation of other reefs.



Source: The Ocean Agency; Coral reefs, Okinawa, Japan

Globally, coral reefs support the livelihoods of 500 million people, meaning the economic impacts of coral bleaching are likely to be profound.[26] The Great Barrier Reef alone—which has seen persistent decline in coral extent in recent decades (Figure 8)—may face economic losses of US $1 billion in tourism spending, 10,000 jobs, and 1 million annual visitors as severe bleaching in the reef continues.

Decline of coral cover on the Great Barrier Reef | FIG. 8



Source: PNAS, 2012.

Impacts on fisheries and management

Changing ocean conditions and marine ecosystems are already impacting global fisheries through changes in productivity, abundance, and the distribution of stocks, as well as through habitat disturbance. Climate impacts will also complicate fisheries management by shifting stocks across traditional management lines and undermining the predictive capacity of assessment models used by scientists. From a livelihoods perspective, these changes will impact food security by redistributing catches, with the greatest impacts expected to occur in tropical regions.[27] Major impacts identified to date include:

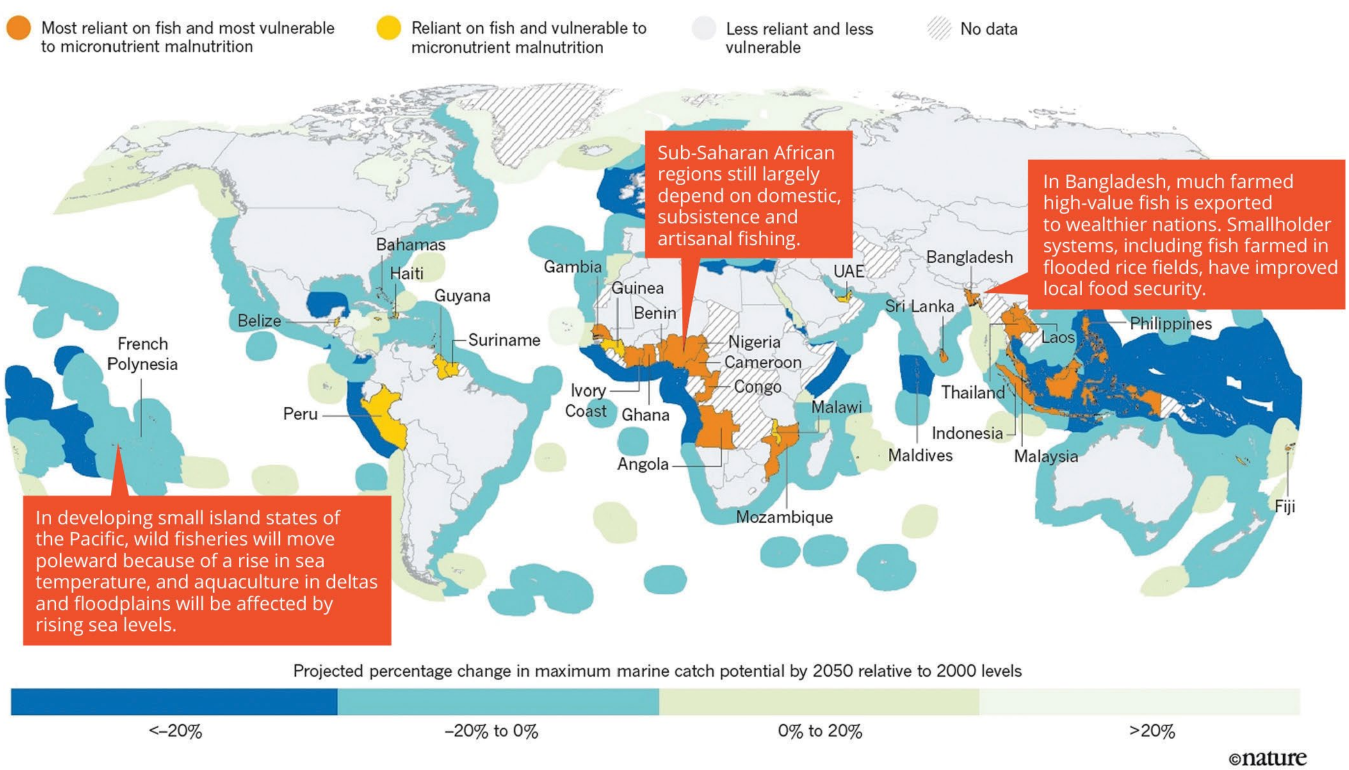
- Fish stocks are already shifting poleward or into deeper waters, at a rate of approximately 10 kilometers per decade.[28] The tropics will be most affected by this shift in distribution, with a reduction in catches of up to 30 percent in some regions, while higher latitudes are expected to see gains.[29] Shifts in distribution present a challenge to managers, particularly in transboundary contexts (as observed in the case of Atlantic mackerel fisheries), as well as in total allowable catch setting (as seen in the example of cod in the Gulf of Maine). These shifts may also challenge the adaptive capacity and jurisdictional authority of managers as new fisheries, such as those in the Arctic, emerge in instances where management and reporting systems do not yet exist.

- Warmer temperatures may lead to decreases in maximum body sizes of wild fish, leading to smaller fish. Such phenology changes could have significant implications on fisheries yields and food security. Under a high emissions scenario, the maximum weight of fish communities is projected to shrink on average by 14-24 percent globally from 2000 to 2050.[30] Decreases in both growth and body size will reduce the overall productivity of fish populations and catch, in addition to impacting ecosystem dynamics as whole.

- While the net costs of climate change will outweigh benefits, certain coastal communities may derive short-term advantages from these changes.[31] One such example is the Arctic region, which could see the opening and expansion of fishing grounds, given decreased sea ice coverage and increased biological productivity. According to one model, total fisheries revenue in the Arctic region may increase by around 40 percent by 2050, relative to 2000.[32] However, fundamental changes in that ecosystem, particularly through ocean acidification, could undercut the scale of any benefits and add substantial uncertainty to the region's fisheries potential.

Climate-related impacts could have significant implications on global fisheries revenues and food security. Under a high CO_2 emissions scenario, global fisheries revenues could be reduced by 35 percent more than the projected catch decreases.[33] Climate change is expected to have negative impacts on the maximum revenue potential (MRP) of nearly 90 percent of the world's fishing countries.[34] New research suggests that the reductions in marine fisheries catch and revenue could present malnutrition challenges in dozens of developing countries. Nearly 20 percent of the global population is at risk of nutritional deficiency due to reliance on wild fish. By overlaying 2050 projected fish catch with data on dietary nutrition, it is clear low-latitude developing countries could face significant micronutrient deficiencies as a result of fish declines in coming decades (Fig. 9).[35] Developing countries where the nutritional dependence on wild fish is high may also be at greater risk of unregulated or illegal fishing, growing populations, and ineffective governance.[36]

Overlay of maximum catch potential and dietary nutrition | FIG. 9



Source: Nature, 2016.

> **Nearly 20 percent of the global population is at risk of nutritional deficiency due to reliance on wild fish.**

Implications of the Paris Agreement

There is clear scientific consensus that the future condition of the ocean depends on how aggressively humanity pursues mitigation options.[37] The Paris Agreement, which resulted from the Conference of the Parties 21 (COP21) meeting held in 2015, established the goal of limiting global mean atmospheric temperature rise by 2100 to well below 2 degrees Celsius, if not 1.5 degrees Celsius, above pre-industrial levels.

Even a reduced emissions scenario consistent with the Paris Agreement will not be robust enough to fully protect the ocean, with several marine and coastal ecosystems—from warm-water corals to coastal mangroves—projected to face high risks of impacts well before 2100.[38] The silver lining is that ocean warming and acidification are expected to stabilize around mid-century, assuming that the goals of the Paris Agreement are implemented.[39]

If countries follow through on their recent pledges to meet the Paris Agreement, called Nationally-Determined Contributions, the world may be on track to avoid the business-as-usual scenario (RCP8.5).[40] However, current NDCs fall well short of meeting the 2 degrees Celsius trajectory, which means that additional commitments are desperately needed. As one expert framed the situation, "It is not a question of how much we can benefit from the Paris Agreement, but how much we don't want to lose."[41]

Plastic debris accounts for the largest portion of marine litter in the ocean by volume. An estimated **8 million tonnes of plastic waste** enters the marine environment annually from land-based sources. Plastic debris has been found everywhere from the once-pristine Arctic Ocean to uninhabited South Pacific atolls.

Land-based and industrial pressures

Land-Based Stressors: Blinds Spots and Data Gaps

Dr. Benjamin Halpern

Professor, Bren School of Environmental Science and Management
Director, National Center for Ecological Analysis and Synthesis (NCEAS)

It is easy to feel overwhelmed by the scope and magnitude of human threats to ocean ecosystems. The list of threats is familiar at this point: climate change, overfishing, eutrophication and dead zones, ocean acidification, invasive species, coastal development, habitat destruction. And the list is growing to include marine debris, microplastics, light and noise pollution, deep sea mining, and more. As a scientist, how do I make sense of all of this when trying to understand and predict how species and ecosystems respond to human pressures? And as a resource manager or philanthropist, how does one figure out where to prioritize allocation of resources and actions?

I have spent the last decade digging into these questions, tracking down data on each type of stressor to figure out what is known and unknown, expanding my work beyond just threats to also address how nature benefits people, and developing methods to put everything together in a structured, informed, and transparent way. From this work I offer four take-home messages.

The most pressing issue is . . . it depends. This is an infuriating answer for policymakers and conservationists, and one that scientists are accused of giving too often. But it really does depend. It depends on scale (e.g., global, a country, a particular bay) and scope (e.g., a species, a habitat type, the whole ecosystem). Globally, the greatest threats are climate change and overfishing. For a particular coastal bay or tropical island or threatened species, it could be eutrophication from watershed runoff, shoreline hardening from coastal development, or one of a host of other issues. The point is, you must know the context and think about the full suite of stressors and how they might interact to know what is going on. Only then can you figure out where, and how, to act to protect that patch of ocean.

People focus too much on single pressures. It makes sense why people do this—it is easier to study a single threat or act on a single pressure. Reduce fishing by creating a marine protected area. Study how warming oceans affect coral reefs. Ban plastic bags. These are all important measures but may sow confusion about the root causes of ocean degradation or have little effect on improving ocean health, and may even do unintended harm. We know that multiple stressors are ubiquitous and that stressor interactions can lead to surprises, yet single-issue strategies predominate and ignore all of this. We still know shockingly little about how three, four, or more simultaneous stressors interact to affect species and ecosystems, and management rarely has the capacity (or mandate) to address more than one issue at a time.

We know a lot, but what we don't know is remarkable. We are awash in data, from high-resolution satellite imagery to thousands if not millions of survey transects, along with many other sources of data. These data tell us a lot about how the oceans work, what benefits they provide us, and how they are changing. Yet profoundly important data gaps remain, including two that are particularly surprising. For the vast majority of the ocean, we know almost nothing about the extent or condition of habitats, yet habitats are the foundation for whole ecosystems and the source of innumerable benefits to humanity. Additionally, for most of the world we do not know how much of a country's economic health and workforce is supported by coastal and marine resources, even though policy, investment, and conservation decisions are highly dependent on this kind of information.

I remain an optimist, but the window of opportunity is closing. The impact of human activities on the ocean is vast and, in most places, growing. Yet there are many bright spots, where cumulative impacts remain low or are improving and oceans are still healthy. Effective management can make a substantial difference, in part because oceans remain fairly resilient (for now). Identifying the most pressing threat(s) to a place and accounting for uncertainties in what we know and do not know form the foundation for effective management. Spending time and money on pressures or issues that have little impact on a region or little importance to people will do little to improve ocean health, and could even jeopardize it.

Lessons learned are helpful, but translating those lessons into concrete guidance and actions makes them meaningful. What do these lessons mean for a foundation or an individual interested in making an investment for change? If the goal is to engage the public, then focusing on, for example, a plastic bag ban may be a good strategy. To make a substantial difference in improving ocean health, there are better places to focus time and resources, including the following:

- **Invest more in understanding how ecosystems and human systems respond to different combinations of multiple stressors.** Any insights from this work will be powerfully important. And support policy initiatives that embrace this approach to management.
- **Help fill key data gaps.** It is not sexy science to do baseline, long-term monitoring, but it is fundamentally important. We cannot effectively manage ecosystems if we do not know what is in them, where they are, and how they are doing. In particular, we need to map and monitor all habitat types globally at high resolution. Ideally, such mapping should be performed on a regular basis to track change.
- **Support environmental data science training.** Pulling together and prepping highly varied data, analyzing the data and visualizing results in transparent and repeatable ways, and communicating results to different audiences are all critical to environmental problem solving, but the skills underlying these tasks remain nascent for most environmental scientists.
- **Coordinate efforts and resources to help mitigate the impacts of climate change,** through policy and technology and shifting people's behavior. We know enough about climate change impacts to require bold action, now.

I don't know exactly how much time we have left before we do irreparable damage to the oceans, but it is certainly in the order of a few decades, at most. As it will be much costlier to fix things in the future, any improvements now will pay large dividends.

Land-based and industrial pressures on the marine environment

Cumulative human impacts on the global ocean

No area of the ocean is completely untouched by human activity. Beyond the impacts from fisheries and climate change, the marine environment is influenced by a wide range of physical alterations (coastal habitat loss and changes in freshwater inputs), chemical alterations (eutrophication, plastic debris, and toxic contaminants), and direct effects on wildlife (invasive species, vessel strikes, and acoustic disturbances).

Attempting to assess these myriad threats is difficult due to widespread data gaps and geographic variation; indeed, the field is largely defined by what we do not know. Attempts to rank ecosystem-level threats from human stressors have highlighted the suite of effects associated with climate change (including sea surface temperature, acidification, and ultraviolet radiation) in addition to commercial fishing, coastal habitat destruction, and pollution (Fig. 1).[1]

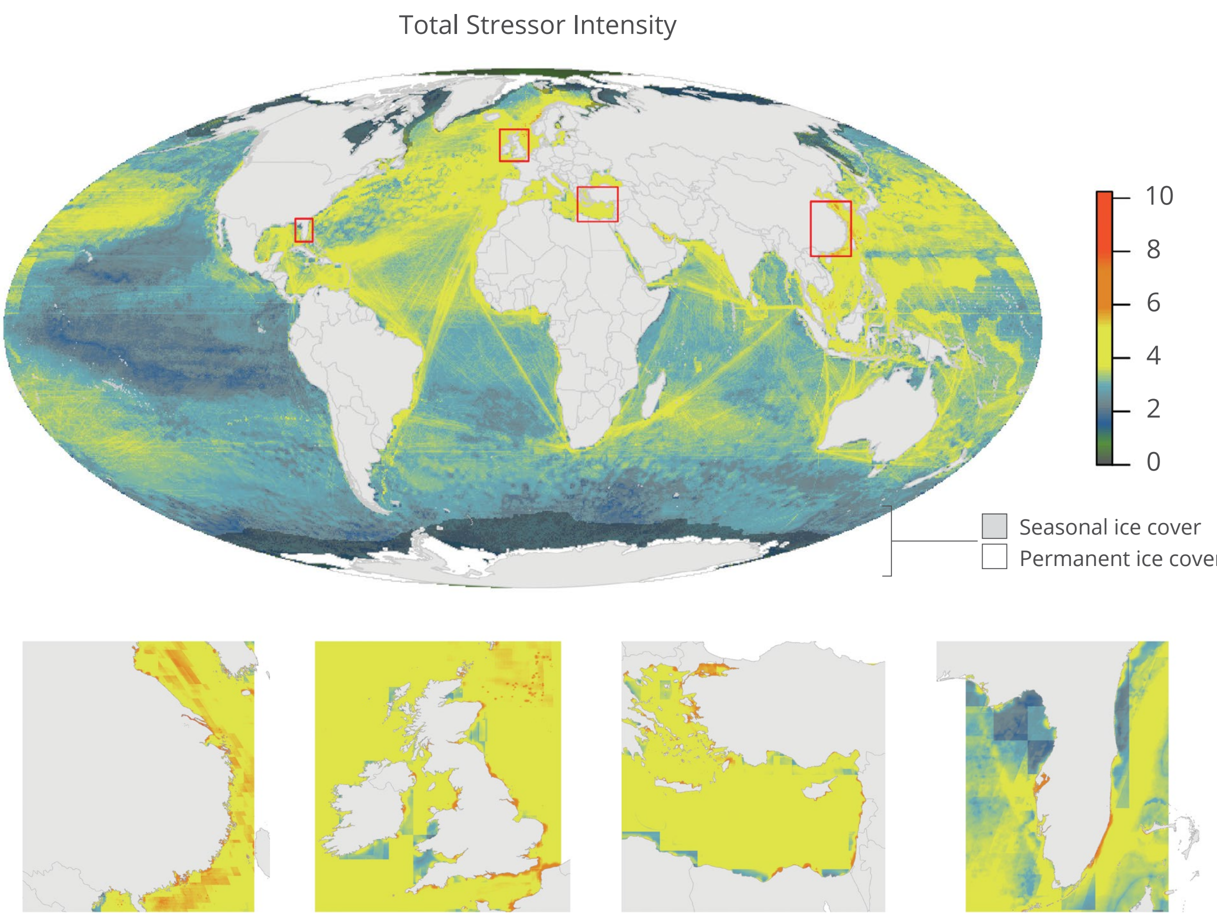
Ranking of human threats to the marine environment based on ecosystem-level assessments | FIG. 1

(1 REPRESENTING THE GREATEST THREAT)

RANK	IMPACT AVERAGED ACROSS ECOSYSTEMS
1	Increased sea temperatures
2	Demersal, destructive fishing
3	Organic, point-source pollution
4	Hypoxia
5	Increasing sediment
6	Coastal development
7	Direct human disturbance
8	Organic, nonpoint pollution
9	Coastal engineering
10	Sea-level rise
11	Nutrient input
12	Demersal nondestructive fishing
13	Acidification
14	Species invasion
15	Nonorganic, point-source pollution
16	Recreational fishing
17	Nutrient input, oligotrophic waters
18	Harmful algal blooms
19	Nonorganic, nonpoint-source pollution
20	Aquaculture
21	Benthic structures
22	Atmospheric pollution
23	Ocean-based pollution
24	Freshwater increase
25	IUU fishing
26	Commercial activity
27	Disease
28	Decreasing sediment
29	Ecotourism
30	Artisanal, nondestructive fishing
31	Freshwater decrease
32	Offshore development
33	Artisanal, destructive fishing
34	Pelagic, high bycatch fishing
35	Ozone/UV
36	Ocean mining
37	Pelagic, low bycatch fishing
38	Aquarium fishing

A research effort to map the cumulative impact of anthropogenic stress on 20 global marine ecosystems confirmed that no part of the global ocean is without human influence.[2] "Hotspots" of cumulative impact exist where multiple stressors overlap, notably in the North Sea and in the South and East China Seas (Fig. 2). In nearshore coastal waters close to densely populated areas, the impact of multiple stressors tends to be most acute. Unsurprisingly, the geographic areas least disturbed by human stressors are concentrated in the poles and in remote swaths of the central Pacific.

Cumulative human impact to marine ecosystems | FIG. 2



A: China Sea B: North Sea C: Mediterranean Sea D: Florida coast

Impact scores are based on 19 anthropogenic stressors. Colors are assigned to 10 quantiles in the data. Areas of permanent sea ice are shaded white, and the area within maximum sea ice extent is masked to indicate where scores are less certain because change in sea ice extent could not be included.

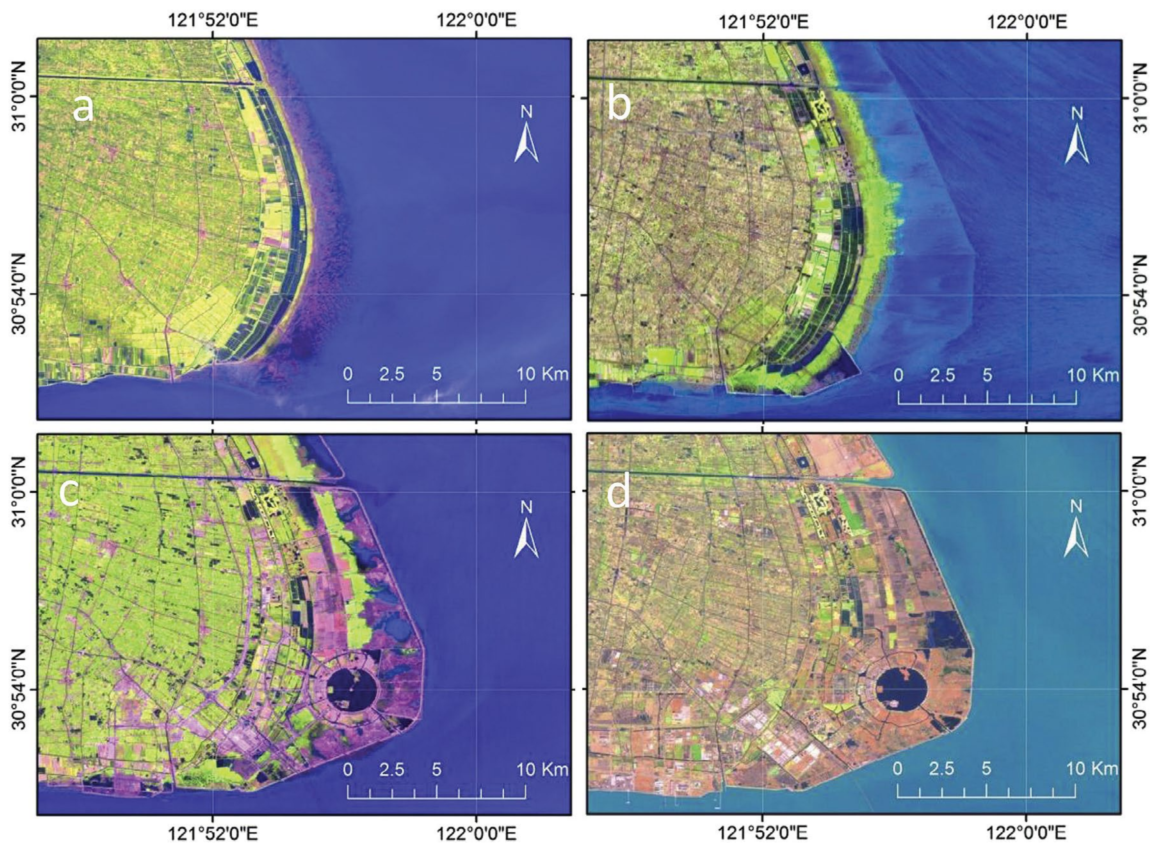
Source: Nature, 2015.

Continued coastal habitat conversion

Beyond fishing and climate change, coastal development and associated habitat loss has been the most obvious threat to the nearshore environment. Draining wetlands, clearing mangrove habitat, filling in estuaries, and hardening shorelines all affect the complex biological interactions between nearshore and offshore habitats.

We lack reliable figures on development trends at a global level. Half of humanity lives within 150 km of a coastline, and increasing urbanization and population growth are contributing to the gradual decline of environments at the coastal interface.[3] According to the IPCC's best estimates, there has been a 30 percent loss of coastal wetlands worldwide.[4] In some watersheds the impacts can be more acute. For example, reclamation of coastal land has occurred extensively along China's coasts due to rapid economic development and industrialization. Since 1949, China has lost over 50 percent of its coastal wetlands.[5] Between 1985 and 2010, nearly 800,000 hectares (8,000 km^2) were reclaimed in coastal China (for example, see Fig. 3).[6] The trend increased sharply after 2005 and is strongly associated with the increased industrial development and urbanization that occurred during this period. Shoreline hardening and the resulting loss of natural buffers can increase the exposure of low-lying areas to accelerated sea level rise and storm surge.

Satellite imagery of coastal reclamation in Nahui shore near Shanghai | FIG. 3

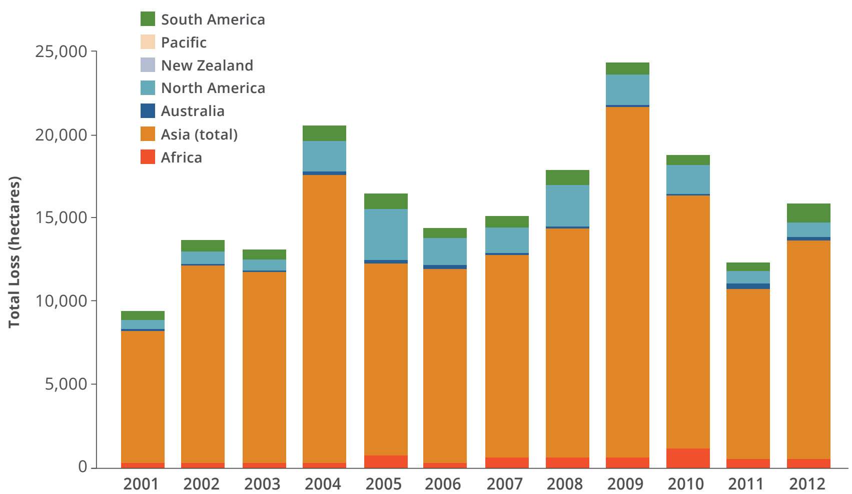


Source: Estuarine, Coastal, and Shelf Science, 2016.

Coastal reclamation of the Nahui shore for the coastal city of Shanghai from 1990 to 2010 with Landsat 5 TM imagery.
a) Year 1990; b) Year 2001 with reclamation; c) Year 2005; and d) Year 2010.

The loss of mangrove forests worldwide has been particularly striking, making them the most threatened major coastal habitat in the world.[7] Between 20 to 35 percent of mangrove area has been lost since 1980 alone.[8] According to data from the Global Forest Watch, an online forest monitoring platform using satellite data, there was a global loss of 192,000 hectares (474,000 acres) of mangroves between 2001 and 2012, or five percent of the remaining stock (Fig. 4).[9]

Mangrove tree cover loss by year (2000-2012) | FIG. 4



Source: World Resources Institute, 2015

Asia has been an epicenter of mangrove decline, with annual loss rates nearly double that of the global average.[10] Throughout much of Asia, conversion to aquaculture and other forms of agriculture have been a substantial driver of change, especially in Myanmar, Thailand, Indonesia, Bangladesh, and Sri Lanka.[11] The many other drivers of mangrove loss include coastal development, sedimentation, hydrological changes, and extreme weather events. At least 40 percent of the animal species restricted to mangrove habitat that have been assessed under IUCN Categories and Criteria face elevated risk of extinction due to significant habitat loss.[12]

Mangroves are part of a dynamic coastal system and provide a range of important ecosystem services, from sustaining fisheries to maintaining water quality through the uptake of pollutants and cycling of nutrients. An estimated 120 million people live within 10 km of significant mangrove areas, with the majority located in Asia and West and Central Africa. The role of mangroves in maintaining water quality can be particularly valuable in areas with high nutrient runoff; in areas where mangrove deforestation is accelerating, the ability to preserve water quality in the face of increasing pollution is placed at risk.

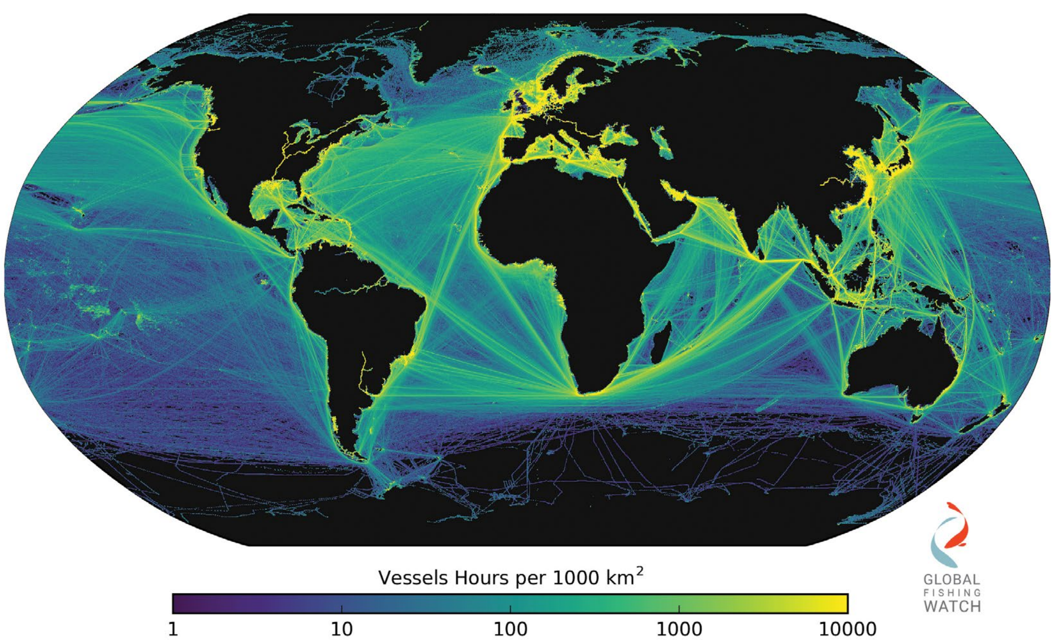
Global shipping on the rise

The volume of global maritime traffic continues to grow, with direct and indirect ramifications for the marine environment. Between 1992 and 2012, the number of vessels on the global ocean increased four-fold.[13] Shipping traffic increased in every ocean basin during that time period, aside from off the coast of Somalia, which has seen a near halt in commercial shipping since 2006 due to increased piracy.

Shipping affects the marine environment in several often-diffuse ways. Ballast water discharges can introduce invasive species and disease. Vessel noise can interfere with communication patterns of marine species. Wildlife collisions can injure or kill marine mammals. And pollution from daily operations, spills, and dirty fuel use can degrade water quality.

The following map of global shipping routes (Figure 5) is a visualization of nearly 5 billion positional Automatic Identification System (AIS) messages from more than 250,000 unique nonfishing vessels in 2016.[14] Messages were collected by satellites and a network of terrestrial receivers along the world's coastlines. AIS messages were then processed by Global Fishing Watch, with thicker yellow lines depicting more heavily trafficked shipping lanes in the map below.

Density of non-fishing vessels with AIS in 2016 | FIG. 5



Source: Global Fishing Watch, 2017.

In addition to general increases in traffic on existing shipping lanes, declining sea ice is opening new shipping routes through the Arctic. Shipping lanes in the Arctic are attractive to industry in that they promise to reduce transit distance and time to many destinations (Fig. 6). Experts are concerned that opening the Arctic—a uniquely fragile marine environment—to industrial activities such as shipping could have profound environmental consequences, from increased noise pollution to oil spills.[15]

The appeal of shorter transit distances is only one factor in determining routing; challenging and often unpredictable weather conditions mean that operating in the Arctic will continue to present complex risks.[16] Ships sailing through the Northeast Passage (across Northern Russia) declined from a peak of 71 vessels in 2013 to only 18 vessels in 2015, partly due to lower oil prices, insurance considerations, and safety concerns.[17] Meanwhile, several countries—including Russia, China, Iceland, Canada, and the United States—have made preparations in recent years to position the Arctic as a busy future global shipping route in coming years.[18] The Chinese government is promoting the trans-Arctic shipping route as a breakthrough that will enhance the country's export-driven economy.

Distances and potential days saved for Asian transport from Kirkenes (Norway), and Murmansk (Russia) | FIG. 6

	VIA SUEZ CANAL			THROUGH NORTHERN SEA ROUTE			DAYS SAVED
Destination	Distance (km)	Speed (Knots)	Days	Distance (km)	Speed (Knots)	Days	
Shanghai, China	12,050	14	37	6,500	12.9	**21**	**16**
Busan, Korea	12,400	14	38	6,050	12.9	**19.5**	**18.5**
Yokohama, Japan	12,730	14	39	5,750	12.9	**18.5**	**20.5**

Source: Tschudi Shipping Company A/S, 2016.

"I realized that Arctic shipping is coming, and that it is, in some ways, already here. The Chinese are taking the long view and they're building ships, icebreakers, and ports to capitalize on the future, which may not be as far off as many think."

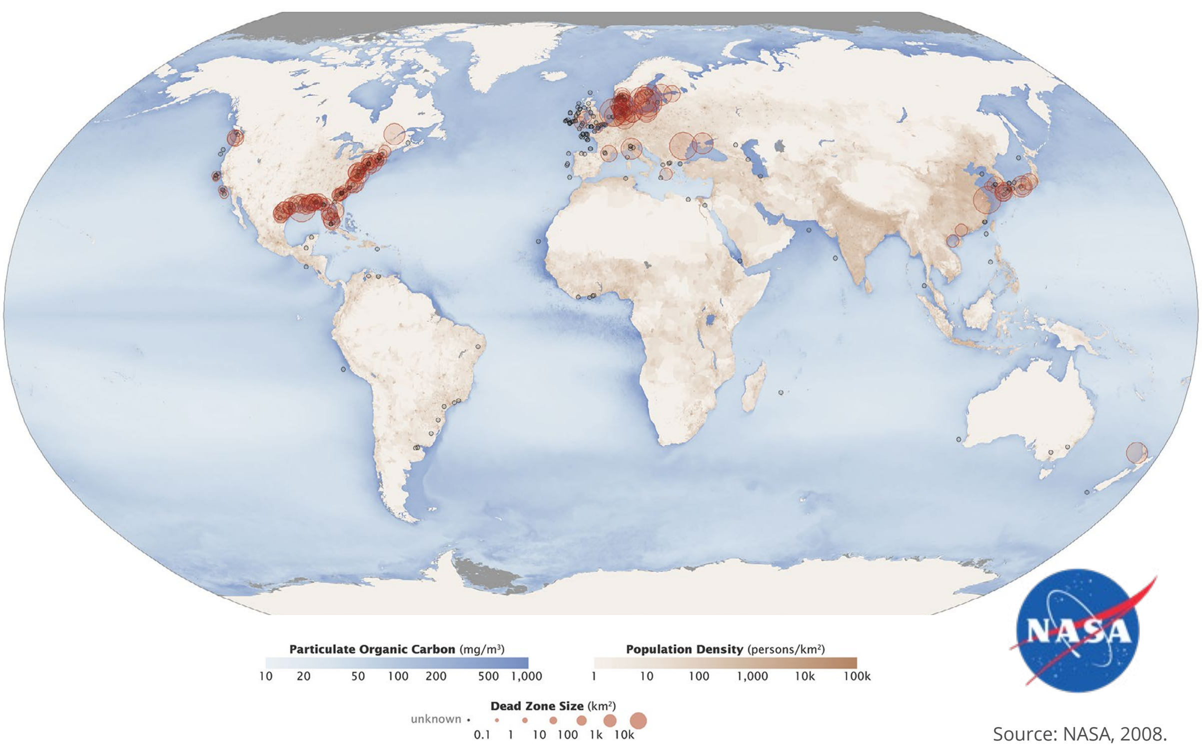
–Rob Huebert, Associate Political Professor at the University of Calgary and a former member of Canada's Polar Commission

The unknown toll of pollution

The aggregate effect of pollution on the marine environment is not known, but can only be presumed to be worsening.

The most common form of pollution entering the marine environment is large-scale nutrient runoff, associated with eutrophication and subsequent hypoxia events, or "dead zones." As a proxy for eutrophication, the size and number of marine dead zones have increased exponentially since 1960.[19] According to one estimate, dead zones have been reported in more than 400 systems globally and affect an area larger than 245,000 km^2, representing a key stressor on marine ecosystems.[20] Hypoxic zones tend to occur downriver of locations where human population density is high. The most reliable maps portraying the global distribution of hypoxic zones (Figure 7) primarily point to hotpots in North America and Northern Europe, presumably due to the absence of data in nearly every other region of the world.[21] Data and monitoring are limited in countries such as China and India, which would be expected to have a higher incidence of dead zones than depicted on the map given their population density and levels of agricultural runoff.

Aquatic Hypoxic Zones | FIG. 7



Source: NASA, 2008.

Red circles on this map show the location and size of many of dead zones.
Black dots show where dead zones have been observed, but their size is unknown.

Map by Robert Simmon & Jesse Allen; based on data from Robert Diaz, Virginia Institute of Marine Science (dead zones); the GSFC Ocean Color team (particulate organic carbon); and the Socioeconomic Data and Applications Center (SEDAC) (population density).

In contrast to underwater hypoxic zones, oil spills may represent the most visible form of marine contamination. Total oil pollution has increased in recent decades, with oil entering the ocean through spills, ballast water, refinery maintenance, and small-scale dumping from land-based sources.[22] Though significant oil spills from tankers (e.g., the Exxon Valdez) have garnered major headlines in the past, the number and size of such accidental spills have decreased in recent decades. In the 1970s, the annual amount of oil entering the marine environment from tanker spills was approximately 314,000 tons; during the 2000s, the average annual amount had decreased to 21,000 tons.[23] On the other hand, spills caused by aging, poorly maintained, or sabotaged pipelines have increased. The Russian Arctic, the Niger Delta, and the northwestern Amazon have been hotspots for this type of recurring pollution. There is no clear trend for marine blowouts, though deep-water well failures can be difficult to cap and can lead to significant discharges of oil, as seen in the case of the 2010 Deepwater Horizon in the Gulf of Mexico.[24]

Persistent organic pollutants (POPs)—including compounds such as pesticides, pharmaceuticals, and industrial chemicals—and contaminants of emerging concern (CECs) represent a more insidious and pervasive threat to marine wildlife given that they have long half-lives and accumulate over time, including at higher trophic levels.[25] The complete impacts of POP compounds are not known, but POPs are linked to deformation, cancer, and reproductive failure. POP compounds have been reported in all parts of the ocean, both geographically and at all depth levels.

Although the total distribution and concentration of POPs is not clear, monitoring of marine mammals provides a glimpse into global trends involving the concentration of POPs. Due to their long half-lives, the compounds can persist for several decades, both in the open ocean and in wildlife populations, even after the chemicals have been banned from use. Polychlorinated biphenyls (PCBs) were detected in high concentrations in wildlife in the 1960s, leading to a ban on PCB use and manufacturing across several countries. In 2001, the Stockholm Convention included PCBs on its list of “Dirty Dozen” POPs for elimination globally. In 2009, the Stockholm Convention added a class of nine POPs (“the Nasty Nine”) for elimination.

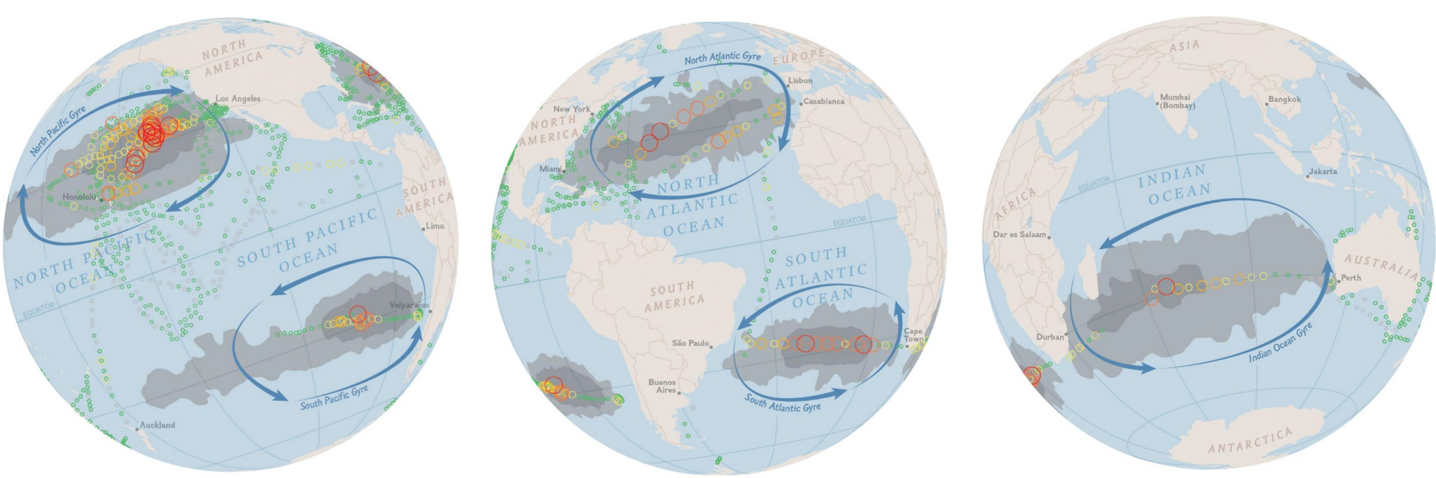
Following these restrictions, there has been an observed decrease in the concentration of certain POPs, including PCBs and the insecticide DDT, in tissue samples of many wildlife populations, including smaller marine mammals such as the grey seal and otter. At the same time, concentrations of PCBs still persist at excessively high levels in other marine mammals, such as orcas (killer whales) and bottlenose dolphins in the northeast Atlantic and several cetacean species in the Mediterranean Sea.[26] These marine mammals are prone to accumulate high concentrations of POPs given their high fat content and position at the top of the marine food web. The orca, in fact, is considered the most highly PCB-contaminated species on Earth. Just as PCBs are a persistent pollutant, the pesticide DDT has rapidly declined in use yet continues to accumulate in the ocean.[27] The year of peak burden of DDT absorption in the ocean was 1977. Since then, total concentrations of DDT in the global ocean have declined, while large sea areas—including the western North Atlantic—continue to accumulate the pollutant.[28]

In contrast to the declining production of select POPs globally, there is an escalating problem of plastic debris in the ocean. Plastic debris accounts for the largest portion of marine litter in the ocean by volume, with an estimated 8 million tonnes of plastic waste entering the marine environment annually from land-based sources.[29]

Models of the worldwide distribution of plastic in the open ocean indicate that plastics accumulate where ocean currents collect debris in gyres due to wind patterns and currents (Fig. 8).[30] The North Pacific Ocean is thought to have the highest concentration of plastics, due in part to the large population on the eastern coast of Asia, as well as wind patterns and ocean currents. It is projected that 15 to 51 trillion plastic pieces (93,000 to 236,000 tonnes) are floating on the ocean surface at any given time.[31] These data underscore the global distribution and pervasiveness of ocean plastics, but also highlight a critical remaining research question: Where is the “missing” plastic? In other words, how do we reconcile the mismatch between the estimated amount of plastic entering the ocean and the amount actually observed?

Plastics are stable and highly durable; materials experts predict they are capable of persisting hundreds to thousands of years. The characteristics that make plastics versatile and widely used—they are lightweight, durable, inexpensive—are the same reasons plastics pose a significant ecological threat when they enter the marine environment. Researchers estimate that over half of the world’s sea turtles have plastics in their gut.[32] That number for seabirds is thought to be over 60 percent. By 2050, researchers predict that around 95 percent of all seabirds will have ingested plastic lodged in their digestive tracks, which is particularly concerning given the current decline of at least half of all seabird species.[33] Plastic can impact animals at every level of biological organization, altering genes, cells and tissues, causing death and altering the size of a population or structure of a community. Plastics have also infiltrated the marine food chain, including contamination of fish and shellfish for human consumption.

Concentrations of plastic debris in surface waters of the global ocean | FIG. 8



The maps depict concentrations of plastic debris in surface waters of the global ocean. Colored circles indicate the measured number of plastic items (in thousands) per square kilometer. Gray areas indicate the accumulation zones predicted by a global surface circulation model. Dark and light gray represent inner and outer accumulation zones, respectively.

Measured number of plastic items per sq km (in thousands)

0 | 0 - 50 | 50 - 150 | 150 - 350 | 350 - 700 | 700 - 3,500

Inner accumulation zone — Outer accumulation zone

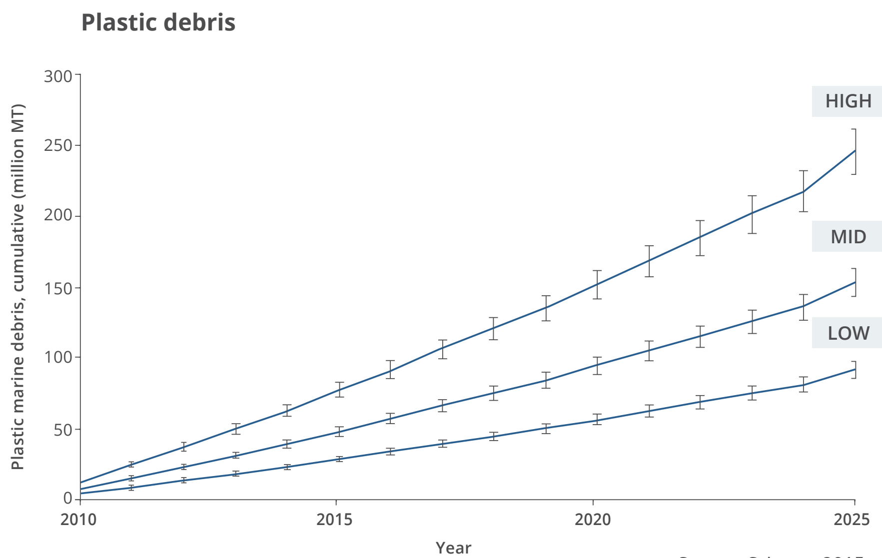
Source: PNAS, 2014.

Used with permission from lead author Andrés Cózar Cabañas, Universidad of Cádiz, Spain.

While much attention has been devoted to macroplastics (e.g., bottles and bags) over the past decade, plastic debris from microfibers is the next frontier of the plastic pollution challenge. Microfibers have been reported in aquatic habitats (both freshwater and marine) across the globe. In some cases, they are the most common type of marine debris found in habitats and inside animals,[34] including in fish and shellfish purchased from public fish markets.[35,36] Laundering clothing is a major source of fiber emissions, as microfibers enter wastewater via washing machine effluent.[37,38]

Plastic production has increased dramatically in recent decades, from 14 million tonnes in 1964 to 311 million tonnes in 2014.[39] This figure is expected to double again over the next 20 years.[40] One study estimated that we will not reach the point of "peak global waste" prior to 2100 given increased per capita consumption, particularly in urban areas and developing countries (Fig. 9).[41] The extent and quality of waste management remains a key determinant in terms of which countries contribute the most significant plastic waste inputs per capita from land into the ocean. Strategies to reduce plastic waste will require a combination of improvements in infrastructure, "downstream" waste management (e.g., expanded recovery systems and greater producer responsibility), and behavioral adjustments at the consumer level. In the context of industrialized countries, reducing waste and the generation of single-use plastics are immediate steps that can be taken; in the context of developing countries, investments in infrastructure will be a key component of long-term solutions.[42]

Estimated projections of mismanaged plastic waste input to ocean, across conversion rates (2010-2025) | FIG. 9



Source: Science, 2015.

Estimates reflect inputs of plastic waste by populations living within 50 km of a coast, plotted as a cumulative sum from 2010 to 2025, across assumed conversion rates of mismanaged plastic waste to marine debris (high, 40%; mid, 25%; low, 15%). Error bars were generated using mean and standard error from the predictive models for mismanaged waste fraction and percent plastic in the waste stream.

The quality of waste management systems remains the key determinant in terms of which countries contribute the most significant plastic waste inputs per capita from land into the ocean.

The designation of large-scale marine reserves has risen in recent years. In 2015, the Government of Palau set aside **80 percent of its EEZ** as a no-take reserve. The Papahānaumokuākea Marine National Monument in the Hawaiian Islands, pictured here, was quadrupled in size in 2016 and stands as one of the largest MPAs in the world.

Marine Protected Areas (MPAs)

The role of donor participation in reaching the Aichi Target 11

Anne Walton
Independent Consultant/Former Program Manager
International MPA Management Capacity Building Program
NOAA

The marine environment makes up nearly 70 percent of our world by surface area, yet only about 3 percent of the ocean is part of the global network of marine protected areas (MPAs). The Aichi Target 11 sets a new bar, calling for the protection of 10 percent of global coastal and marine areas by 2020. Philanthropic funds have supported the Aichi target in two distinct areas: (1) designating new MPAs, particularly large-scale MPAs; and (2) building the capacity of MPA practitioners to more effectively manage MPAs, both within communities and governments, from the local to national level.

Designation of large-scale MPAs

Efforts toward meeting the Aichi Target 11 goal have been primarily devoted to designating large-scale MPAs. Recent success in capturing large swaths of ocean in MPAs is largely attributable to major donor participation. Notable examples include the Pew Charitable Trust's support of the recent expansion of Papahanaumokuakea (1,500,000 km^2) and Pitcairn (830,000 km^2); the Last Ocean Charitable Trust's Ross Sea MPA (1.5 million km^2); and the Global Conservation Fund's Phoenix Island Protected Areas (408,000 km^2). Other mechanisms to support MPA designation include fiscal instruments such as the Seychelles' (400,000 km^2) debt swap with its Paris Club creditors and the Government of South Africa. Governmental efforts toward meeting the target include Palau's protection of its entire exclusive economic zone (EEZ), the Federated States of Micronesia's protection of an additional 185,000 km^2 of its waters, and Cambodia's designation of its first, small-scale MPA (405 km^2).

Partnerships between donors and on-the-ground implementers (primarily the big NGOs) have also been critical to success. In some cases, contributions from donors extend beyond financial support alone. Donors such as Pew are taking an active role in advocacy, campaigning for specific site designations, engaging stakeholders and media support, and effecting policy change.

Capacity building for sustainable management of MPAs

Arguably the biggest challenge created by donor support for MPA designation is securing reliable long-term financing to effectively manage MPAs. Balmford et al.'s Global Cost Model estimates that a worldwide network of MPAs covering 20-30 percent of the ocean would cost US $5-19 billion annually to manage.[1] However, the literature indicates that it is difficult to estimate costs on a global scale due to variability in design. Of concern, governments with jurisdiction over MPAs have demonstrated a lack of commitment, and budgets for MPA management are limited. Funding of site operations, conservation and enforcement programs, and staffing remains outside of reach for most MPAs. That said, the three Our Ocean conferences have generated global ocean commitments valued at over US $9 billion and a commitment to protect 9.9 million km^2 of ocean, or roughly 2.72 percent global coverage.[2] If upheld, these financial pledges will be more than sufficient to meet MPAs' financial needs.

There is already some indication that MPA managers are moving toward securing financial sustainability. The concept of conservation trust funds (CTFs) has been under development for more than a decade—see the Mesoamerican Reef Fund (2004), Phoenix Islands Protected Area Conservation Trust (2009), and Caribbean Biodiversity Fund (2012). New commitments to CTFs are coming online, such as the Blue Abadi Fund for the Bird's Head Seascape (Indonesia) and Monaco's CTF with France and Tunisia. To benefit from these CTFs, MPAs require financial management expertise, strategic partnership building, political support, and a commitment to monitoring, evaluation, and reporting on the use of funds.

Looking forward: future roles for donor support of MPAs

The need for strengthening conservation benefits

Although MPA coverage has expanded of late, the 10 percent target represents only one component of Aichi Target 11. Representativeness and connectivity are critical elements of the target that the global MPA network has not yet met. As we designate new sites and expand existing sites, we need to look more closely at protecting areas of particular ecological or biological importance.[3]

Donor support should be directed toward analyzing the current inventory of MPAs to determine and track how we are meeting the representativeness and connectivity standards. Funding priorities should fill the gaps to: ensure and improve ecological representativeness, increase connectivity for key habitats and species, protect the movement of the life history range and associated habitats for species of concern, and expand coverage for areas of high biodiversity and valuable ecosystem services.

The need for sustainable financing mechanisms for MPAs

Entrepreneurial approaches to financial planning are moving MPA management into new frontiers and ways of thinking. Most MPA managers come into the job having been trained as scientists. A background in business or finance is a rarity, yet MPA managers need to expand and diversify their MPAs' financial portfolios. Future contributions by the donor and NGO communities will play a critical role by ensuring that MPA managers are equipped to identify diversified sources and approaches to income generation.

What's in a Target?

The concept of setting targets is not new in the field of natural resource management, though there is a shorter history of setting targets for global MPAs. The MPA target baseline has shifted multiple times: the Durban Accord (2003) called for 20-30 percent no-take reserve coverage by 2012; the Aichi Target 11 (2010) set a goal of protecting 10 percent of coastal and marine areas by 2020; the Promise of Sydney (2014) advocated for 30 percent coverage with no-extractive activities (under no suggested timeline); and the World Conservation Congress' Motion 53 target (2016) reaffirmed the call for governments to set aside 30 percent of national waters by 2030.

What target will achieve our goal of protecting biodiversity, preserving ecosystem services, and achieving socioeconomic priorities? Since science is unable to support a singular target at the global scale, perhaps we should consider shifting the focus to results-based MPAs, especially in this time of increasing pressure and impacts from human demands on the marine environment—influences that are only exacerbated by climate change. Improving the design and networks of MPAs, along with strengthening the capacity to manage and support MPAs over the long term, might be the best place to set our sights, rather than focusing solely on area of coverage.

Recent trends in MPAs

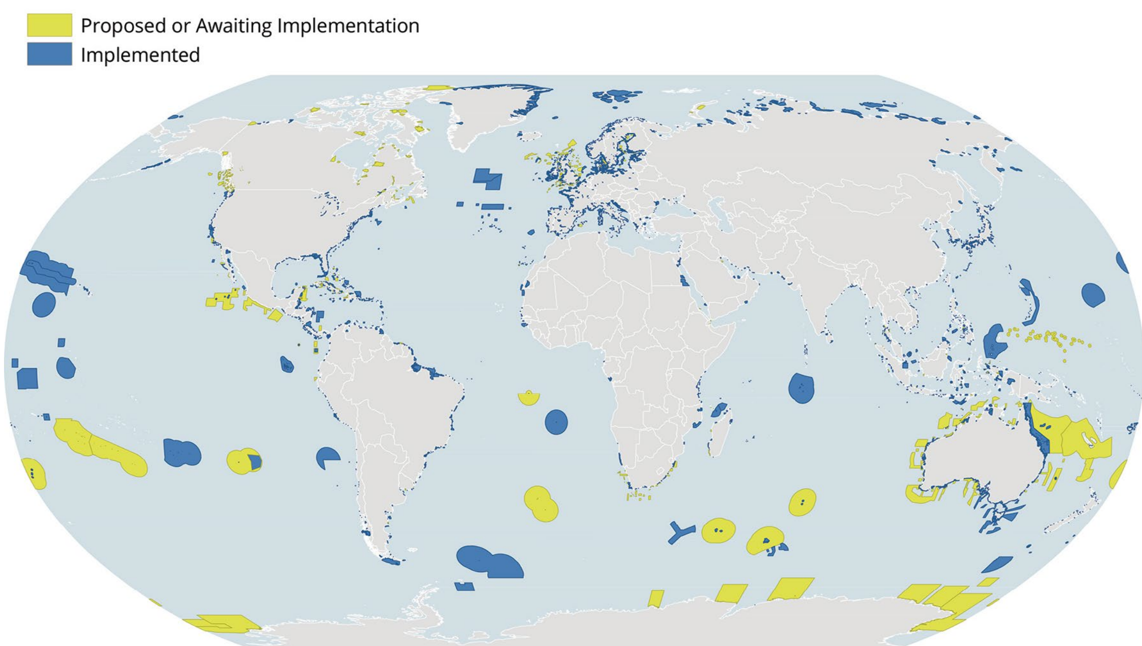
The world has continued to make progress in setting aside portions of the ocean as MPAs.[i] Several international for a and global goals—including the Sustainable Development Goals and the Aichi Biodiversity Targets—have highlighted the role of protected areas as a key strategy for biodiversity conservation and sustainable development.

In 2010, the Parties to the Convention on Biological Diversity (CBD) adopted the 20 Aichi Biodiversity Targets. Aichi Target 11 calls for the conservation of at least 10 percent of coastal and marine areas by 2020.

As the global community has sought to achieve 10 percent protection of coastal and marine areas, a few key trends that have stood out:

1. **There has been a rise in designating large-scale marine reserves in remote areas.** As shown in Figure 1, a small number but a high percentage of the acreage includes large expanses located on the high seas, usually in locations with low human density and low levels of commercial use and industrial fishing. These areas boost the overall coverage of the global MPA network, and many of them are largely untouched given the absence of direct impacts from human activities.

Marine Protected Areas Implementation | FIG. 1

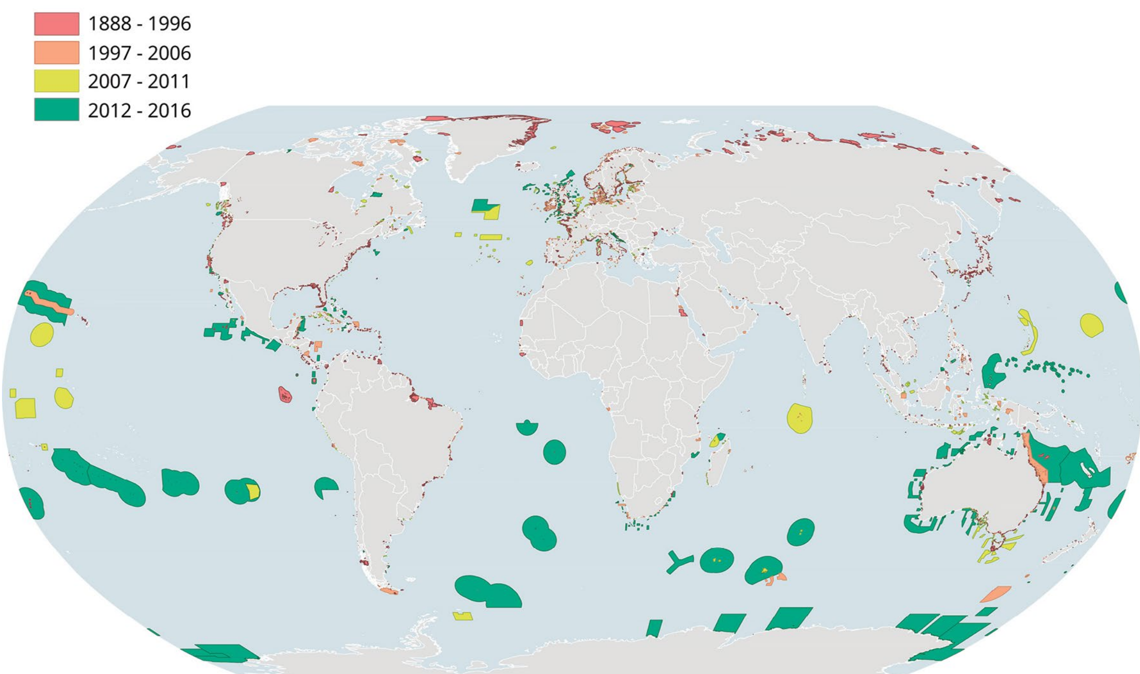


Source: Marine Conservation Institute, MPAtlas (2017)

[i] WDPA uses the IUCN and CBD definitions of protected areas to determine whether a site should be labeled as a "protected area" in the WDPA. The IUCN definition is as follows: "A protected area is a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values." The CBD definition is as follows: "A geographically defined area, which is designated or regulated and managed to achieve specific conservation objectives. There is agreement between the CBD Secretariat and IUCN that both definitions have the same meaning.

2. The rate of MPA declarations has increased in recent years. In fact, the amount of ocean in protected areas has nearly doubled since 2005. Overlaying the yellow coverage in Figure 1 (indicating "proposed" or "awaiting implementation") with the green coverage in Figure 2 (indicating declaration between 2012 and 2016) shows the prevalence of large-scale commitments in recent years. There are a few possible explanations that help explain this trend. First, some governments have turned their attention to offshore ocean areas (still within their EEZs), given concerns that the rate of growth of MPAs in coastal areas may be too slow to reach target commitments. Designating large expanses of the ocean as protected areas is one approach that governments may use to rapidly reach their international obligations. Second, creating vast MPAs can be appealing to political leaders from a legacy perspective. For instance, President Obama created what was then the largest ecologically protected area in the world when he expanded the Papahanaumokuakea Marine National Monument in Hawaii in 2016, a move that bolstered his reputation as a conservation-minded leader.

Marine Protected Areas (Recentness of Implementation) | FIG. 2

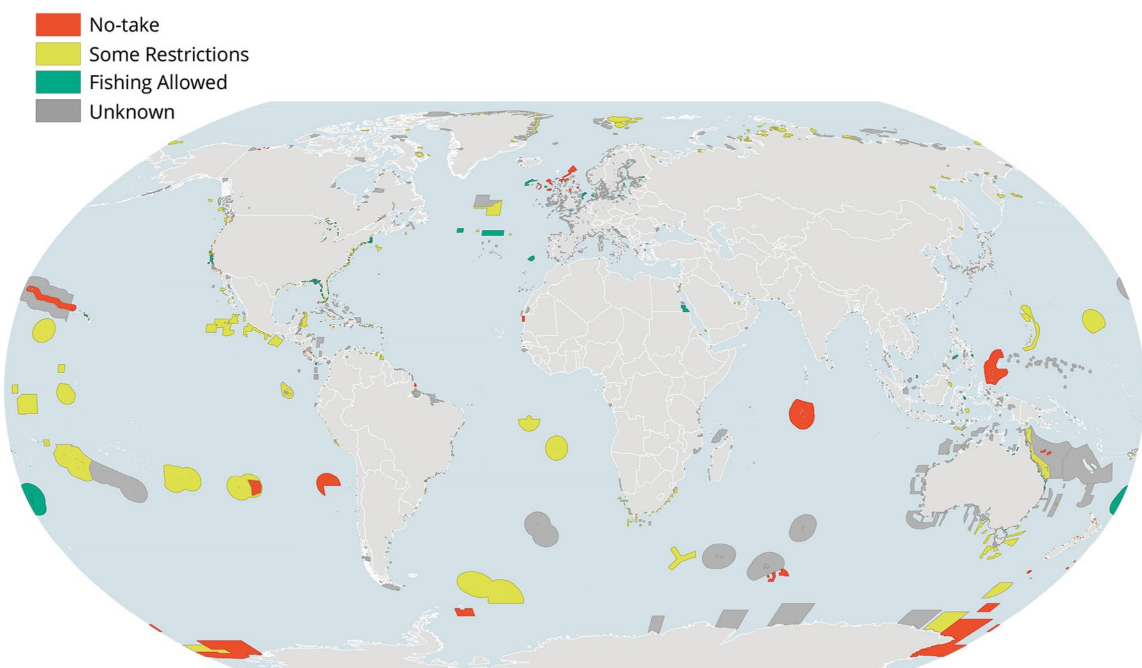


Source: Marine Conservation Institute, MPAtlas (2017)

3. **There have been a handful of countries, particularly in the Pacific Islands, that have become champions of large-scale ocean protection.** A high number of sizeable reserves are located in the western Pacific Ocean and were designated by countries with relatively small populations and comparatively large EEZs under their jurisdiction. The value of designations in this region is magnified by the marine environment's biodiversity value and contribution to livelihoods. The Coral Triangle alone contains 75 percent of all known coral species, serves as habitat for 40 percent of the world's reef fish species, and provides food and livelihoods for millions of people. The Western Pacific has accordingly received significant technical and financial support from donors to protect their marine resources. Additionally, there has been strong momentum and collaboration among governments in the region. As part of the Micronesia Challenge, for example, five governments committed to conserve at least 30 percent of nearshore marine resources across Micronesia by 2020.

4. **There are various levels of protection for MPAs; notable designations have been made in recent years for no-take areas** (as shown in Fig. 3). The Government of Palau set aside 80 percent of its EEZ as a no-take reserve in 2015, the highest percentage of any country in the world. It is expected to implement an enforcement plan for the sanctuary by 2020 and will permit local fishers to continue operating in the remaining 20 percent of the EEZ to supply the domestic market. The Ross Sea is another prominent designation of a large no-take area. In 2016, the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) announced the creation of a new no-take zone in the Ross Sea that prohibits extractive activities, including commercial fishing. Encompassing an area of 598,000 square miles, this MPA off Antarctica ranks as the world's largest marine reserve.

Marine Protected Areas (Level of Protection) | FIG. 3



Source: Marine Conservation Institute, MPAtlas (2017)

Are we meeting the global target?

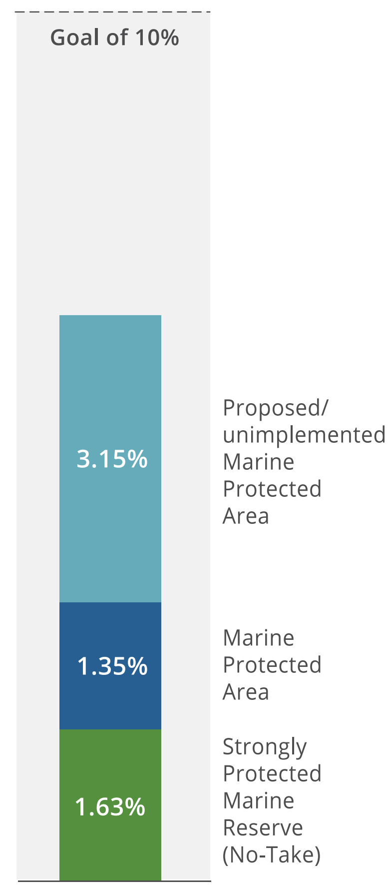
The extent of protected area coverage is one of the core indicators for measuring progress towards the Aichi Target 11. As of 2016, there were 14,688 Marine Protected Areas (MPA) recorded in the World Database on Protected Areas (WDPA), covering 4.12% (14.9 million km^2) of the global ocean and 10.2% of coastal and marine areas under national jurisdiction.[1] The WDPA is a joint project between the United Nations Environment Program and the International Union for Conservation of Nature. Data from the WDPA are used for reporting to the CBD on progress toward reaching the Aichi Target 11 and to the United Nations to track progress toward the 2030 Sustainable Development Goals.

While the WDPA is considered the official source for tracking international conservation targets, it may overestimate the extent of protected area due to its reliance on self-reported data from governments, NGOs, and other stakeholders. The MPAtlas, maintained by the Marine Conservation Institute, uses WDPA data as a starting point and conducts desk research and follow-up verification with individual agencies to address potential over-estimates in reporting.[2] For the purpose of this report, the MPAtlas database is used as the standard data source (Fig. 4).

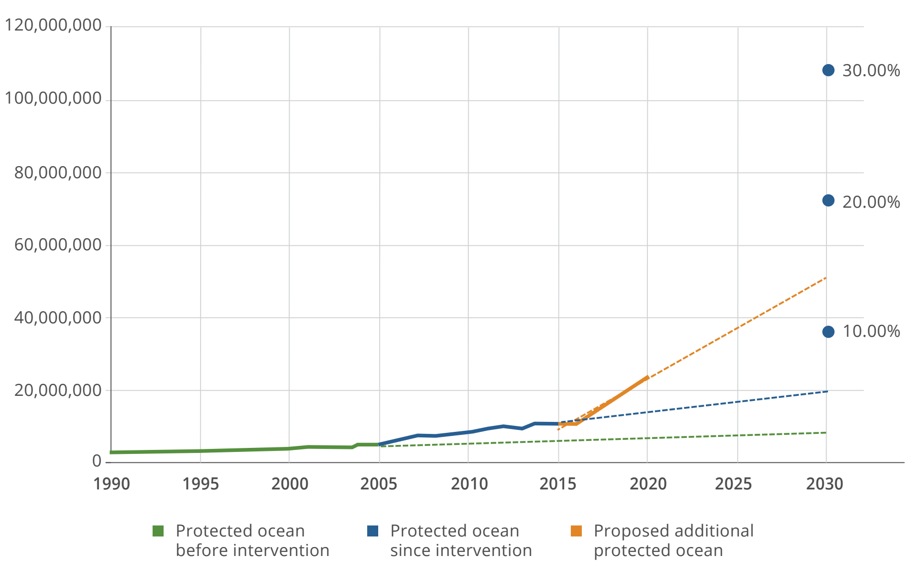
Despite slight differences in reporting between the WDPA and MPAtlas, both sources suggest that the current level of protection is less than halfway toward the Aichi Target 11 of conserving 10 percent of the ocean (Fig. *5*). Implementing the proposed or officially announced MPAs would increase the level of protection to nearly 6 percent of the ocean.

Progress toward protection of oceans | FIG. 4

GOAL OF 10% OCEANS CONSERVED



MPA Global Coverage Trends | FIG. 5



Source: Marine Conservation Institute, 2016.

According to the MPAtlas, only 3 percent of the global ocean is protected in implemented and actively managed MPAs. Slightly more than half of this amount is protected in no-take reserves.

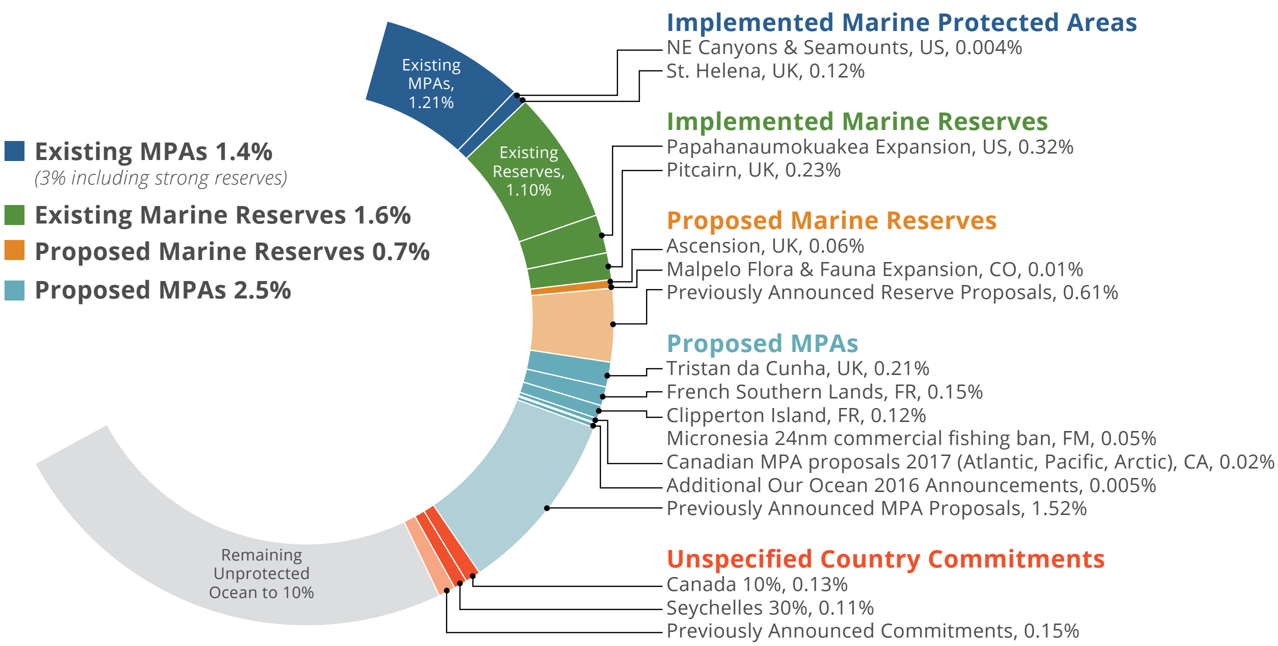
The Pacific Island countries in particular have shown significant leadership toward meeting the Aichi Target 11. At the same time, it is worth noting that a handful of other country governments have played an important role in establishing large-scale MPAs that have advanced progress toward the global target. These countries and their recent designations include:

- United States (Mariana Trench, Northwest Hawaiian Islands)
- United Kingdom (Chagos, Ascension Island, and Pitcairn Islands)
- Chile (Easter Island and Nazca-Desventuras)
- New Zealand (Kermadec Sanctuary)
- France (Austral Islands, French Polynesia)

International conferences, including the "Our Ocean" conference series, have provided a global platform to encourage governments to make formal commitments to ocean protection, including by designating MPAs and other marine reserves (Fig. 6).

Existing and Proposed Marine Protection after Our Ocean Conference | FIG. 6

SEPTEMBER 2016



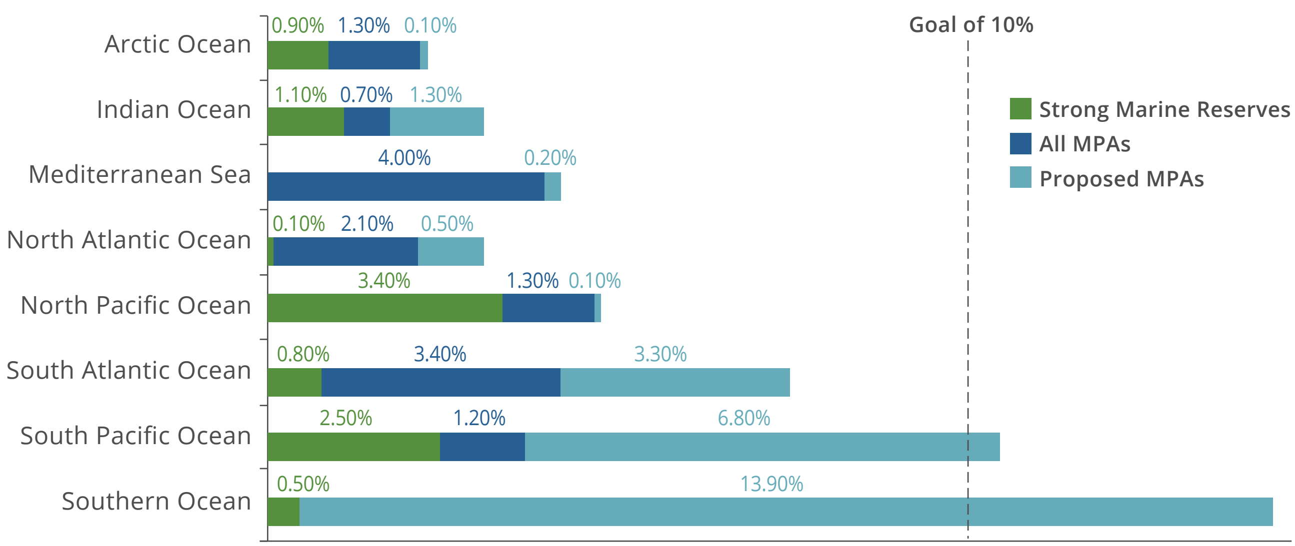
Source: Marine Conservation Institute, 2016.

How do protection levels compare across ocean basins?

If current proposals by the CCAMLR are adopted and implemented, the Southern Ocean would rank as the best protected ocean basin by a large margin (Fig. 7). The South Pacific currently has significant areas set aside, particularly as no-take zones, and is slated to reach more than 10 percent protection coverage if proposed MPAs are implemented.

The Arctic remains one of the least protected ocean basins in the world. Protections for the marine environment in the Arctic remain far behind the proportion of terrestrial environment that is currently protected in the region. In 2016, U.S. and Canadian leadership committed to protect more than 10 percent of the U.S. and Canadian Arctic Ocean by 2020, which may help spur a more focused effort to create a pan-Arctic network of MPAs.[3]

Level of protection by ocean basin | FIG. 7



Source: Marine Conservation Institute, 2016.

The Arctic remains one of the least protected ocean basins in the world.

As the international community works to reach the Aichi Target 11—and begins to consider the next iteration of a global conservation target—a handful of important considerations are surfacing:

1. **What level of financial resources will be needed to reach our conservation targets?**

   A recent study commissioned by the World Wildlife Fund (WWF) estimated that achieving 10 percent coverage of MPAs would cost in the range of US $45-47 billion, while 30 percent MPA coverage would require US $223-228 billion over the period 2015-2020.[4] The estimated benefits, however, are substantial, with models predicting a ratio of benefits to costs from 3 to 20 times. While the benefits of MPAs outweigh the costs in most models, finding the financial (and technical) resources needed to establish and run MPAs is a major undertaking, and governments continue to wrestle with how best to secure those funds in the face of competing priorities.

2. **Should future marine protection efforts focus more explicitly on ecological connectivity and representation to fulfill Aichi Target 11?**

   A 2016 assessment of protected area coverage shows that 36 percent of the world's marine ecoregions have at least 10 percent of their area protected (an increase of 2 percent since 2014).[5] The study found that 22 percent of marine ecoregions still have less than 1 percent of their area protected, highlighting the current gap in ecological representation.[6] The conservation community may evaluate whether more concerted efforts should be made to ensure improved connectivity and representation of areas of high biodiversity value.

3. **What are the prospects for additional, large-scale MPAs in remote areas? To what extent should smaller MPAs in nearshore areas be prioritized?**

   Large-scale MPA designations in recent years have brought us much closer to the global target of 10 percent coverage. Many of these MPAs are situated in open ocean environments with modest human activity. It remains an open question whether the international community should "think beyond the target" to shift its primary focus from the overall area of coverage to nearer shore environments, where direct human impacts and land-based stressors bear the greatest influence.[7]

Appendices

Global Ocean Research Agenda

Proposed areas of research and learning for the philanthropic community

There is a tremendous amount of information that we don't know. To help spur further dialogue about pressing research priorities for the philanthropic community, this report also surveyed the nine contributing authors of the perspective pieces featured in this report to solicit their suggestions about priority areas of learning. The authors' aggregated responses are captured below.

Recommendations for areas of research and learning

1. Wild capture fisheries and aquaculture

- How can we obtain better data cost-effectively—particularly with respect to stock health, potential recovery trajectories for wild fisheries, and the broader economic, social and environmental benefits that would come from it—at the micro-level to support relevant political and industry actors in making management decisions?
- What are the bottlenecks to scaling fishery reform efforts? How can policy and governance changes come about in the fastest, most cost-effective manner? If human capital is a critical missing ingredient, how can we find and deploy the right people with the appropriate set of skills and capabilities to help scale reform? Beyond the fisheries sector, where else has this been attempted?
- What compelling opportunities exist for using technology, including satellite monitoring through Automatic Identification Systems (AIS), to perform global monitoring of fishing activities?
- What is the capacity of wild fisheries and aquaculture production to feed a growing human population, while also minimizing the impact of environmental externalities? In particular, what are opportunities for improving the production and environmental performance of aquaculture?

2. Small-scale fisheries

- Under what conditions is the management of small-scale fisheries most successful? What are the attributes of those fisheries and management systems that have contributed to that success?
- Can we improve our understanding of how different tenure systems have been used to control and govern access to small-scale fisheries, in addition to obtaining better data on the overall size and composition of the sector?
- What are the dynamics of small-scale fisheries value chains and how can they support improved markets for the sector?

3. Climate change

- How can we boost the adaptive capacity of marine and human systems to climate change?
- What is the scope and effectiveness of nature-based solutions in mitigating and adapting climate change impacts in the ocean and coastal communities?
- What are the co-benefits and trade-offs of climate mitigation and adaptation options in achieving other sustainable development goals?

4. Marine Protected Areas

- How do we understand correlations and linkages between socioeconomics, efficacy of MPA design, conservation and biodiversity, localized climate stressors, management capacity, and the role of regulatory efforts? How might this information provide stronger guidance on how best to design and run marine managed areas, from the local to global scale?

5. Land-based threats

- Given that multiple land-based stressors are ubiquitous in most ecosystems (yet our knowledge of them remains very limited), can we map the various pathways of how multiple stressors interact to affect species and ecosystems?
- What are the effects of micro- and nano-plastics on animal and human health?

6. Governance and finance

- Do finance models exist in non-fishery sectors (e.g., agriculture or forestry) to demonstrate the positive catalytic effort of return-seeking capital in changing the management of natural resources?
- How can we ensure adequate and sustained U.S. federal investment in ocean science and technology, such that budget prioritization echoes policy initiatives?
- What is the best approach for engaging and educating a broad public on ocean literacy to bring new perspectives and solutions to ocean issues?

Philanthropic funding data methodology

The philanthropic funding data presented in the Global Oceans Report primarily consist of grant-level data provided directly by staff members at participating foundations or downloaded directly from foundation websites. CEA standardized the data and used the grant descriptions and titles to sort each grant into two taxonomies: one for the ocean-related topic and one for the geographic location of the work. Where there was insufficient detail to categorize a given grant, an "Unspecified" category was used for one or both taxonomies.

For all but one foundation in the report, the grant totals shown represent new commitments made in a given year, rather than the actual amount of funding disbursed in that year. The one exception is the Moore Foundation. The temporal trend of Moore's commitment amounts was highly variable, while its disbursement showed a steady trend. As a result, Moore disbursement amounts are used in all charts, illustrating a trend over time, while commitment amounts are used in all other charts.

In addition, the Foundation Center shared with CEA a list of grants it had categorized as oceans-related between 2009 and 2016 through its recent data collection effort for the "FundingtheOcean.org" database. CEA used this dataset, along with its own, to identify the top 25 ocean funders by total grant commitments from 2010 to 2014. Where the CEA dataset did not already include these top 25 funders, the Foundation Center data were used and recategorized according to CEA's taxonomies. In addition, Foundation Center grants for all foundations (including those outside the top 25 described above) with commitment amounts greater than $100,000 and not already included in the CEA database were categorized and included in the final report dataset.

In total, the Foundation Center data account for 21 percent of the grant commitments shown in the report for the years 2010 to 2014. All of the data used to show trends for the top five ocean funders from 2010 to 2016 were directly collected and categorized by CEA.

OECD CRS oceans funding methodology

The ODA data presented in the Global Oceans Report is sourced from the OECD's CRS database and is available on the OECD's webpage. The CRS database contains all project-level ODA flows reported to OECD by Development Assistance Committee members. These flows include activities channeled through multilateral organizations by donor countries, though general contributions to the regular operating budgets of multilateral organizations are excluded.

CEA began by downloading all CRS project-level data for the years 2007 through 2015. CEA developed a methodology, described below, which used OECD's purpose code categories combined with keyword searches to limit the dataset to oceans-related ODA flows.

First, CEA limited the dataset to include only the OECD Purpose Codes that we identified as potentially containing oceans-related ODA flows. These categories are displayed in the table below.

PURPOSE CODE	PURPOSE NAME	CLARIFICATIONS / ADDITIONAL NOTES ON COVERAGE
S21040	Water transport	Harbors and docks, harbor guidance systems, ships and boats; river and other inland water transport, inland barges and vessels.
23250	Marine energy	Including ocean thermal energy conversion, tidal and wave power.
31310	Fishing policy and administrative management	Fishing sector policy, planning and programs; institution capacity building and advice; ocean and coastal fishing; marine and freshwater fish surveys and prospecting; fishing boats/equipment; unspecified fishing activities.
31320	Fishery development	Exploitation and utilization of fisheries; fish stock protection; aquaculture; integrated fishery projects.
31381	Fishery education/ training	
31381	Fishery research	Pilot fish culture; marine/freshwater biological research.
31391	Fishery services	Fishing harbors; fish markets; fishery transport and cold storage.
32172	Transport equipment industry	Shipbuilding, fishing boats building; railroad equipment; motor vehicles and motor passenger cars; aircraft; navigation/guidance systems.
32268	Offshore minerals	Polymetallic nodules, phosphorites, marine placer deposits.
41020	Biosphere protection	Air pollution control, ozone layer preservation; marine pollution control.
41030	Biodiversity	Including natural reserves and actions in the surrounding areas; other measures to protect endangered or vulnerable species and their habitats (e.g., wetlands preservation).
41050	Flood prevention/ control	Floods from rivers or the sea; including sea water intrusion control and sea level rise-related activities.
41082	Environmental research	Including establishment of databases, inventories/accounts of physical and natural resources; environmental profiles and impact studies if not sector specific.
52010	Disaster prevention and preparedness	Disaster risk reduction activities (e.g., developing knowledge, natural risks cartography, legal norms for construction); early warning systems; emergency contingency stocks and contingency planning including preparations for forced displacement.
41081	Environmental education/training	

A review of a sample set of flows from each purpose code revealed that some codes were primarily comprised of oceans-related flows, while others contained mostly flows unrelated to oceans. As a result, CEA made a determination as to whether flows within each purpose code would be included in the final dataset by default. This determination, listed for each category in the following table, is only relevant where an individual flow was not matched using a set of keyword searches that are described in greater detail below.

PURPOSE NAME	DETERMINATION
Water transport	Include non-matched grants
Marine energy	Include non-matched grants
Fishing policy and administrative management	Include non-matched grants
Fishery development	Include non-matched grants
Fishery education/training	Include non-matched grants
Fishery research	Include non-matched grants
Fishery services	Include non-matched grants
Transport equipment industry	Exclude non-matched grants
Offshore minerals	Include non-matched grants
Biosphere protection	Exclude non-matched grants
Biodiversity	Exclude non-matched grants
Flood prevention/control	Exclude non-matched grants
Environmental research	Include non-matched grants
Disaster prevention and preparedness	Exclude non-matched grants
Environmental education/training	Exclude non-matched grants

To avoid using the default determination for each purpose code as often as possible, we developed a set of keywords that were used in text searches to label individual flows as either oceans-related or not ocean-related, with the latter being excluded from our final dataset. It is important to note that project descriptions for ODA flows were not provided in a standard language, so our keywords include words from the primary languages used in the project description field: English, Spanish, and French. This methodology is not perfect because some project descriptions were provided in other languages (e.g., German) for which no keywords were chosen, and some ODA flows had no project description or an incomplete project description. As a result, there are undoubtedly some oceans-related ODA flows that were excluded from the final dataset and ODA flows unrelated to oceans that were included in the final dataset.

For the OECD purpose codes whose flows were categorically excluded, individual flows were only included in the final dataset if their project description included one or more of the following words or prefixes:

Note: An asterisk (*) indicates that the keyword included a space at the end to ensure no words containing the word fragment were unintentionally included.

ocean	mar*	peche
longline	pesca	acuicultura
tuna	shrimp	pesquera
fischerei	WCPFC	marine
maritime	mariculture	sea turtle
coastal	sea*	coral
beach	mangrove	whale
dolphin	shore	shark
port*	ports*	dock
harbour	fish	harbor
wharf	hydro	océanographie
mer*	ship*	maritime
vessel	estuar	international water
reef	pêche	Pacific
aqua		

For the OECD purpose codes whose flows were categorically included, individual flows were included *unless* they contained one or more of the following words or prefixes:

climate	elephant	landscape
wetland	rhino	plant
agro	carbon	farm
lake	animal	inland
freshwater	road*	bridge*
humanitarian aid	rainforest	stormwater
rain	river	forest
grassland	rangeland	agricultur
car*	vehic	road
bridge	rain	disease
humanitarian	school	earthquake
HIV/AIDS	child protection	health care
healthcare	civil society	poverty reduction
ebola	armed conflict	drinking water
housing	urban	irrigation
automobile	airport	manufacturing
fire	métallogénie	desertification
tierra	dryland	floristique
agro	stream	renewable energy
lago	rio*	roads

As a final step, CEA excluded ODA flows to landlocked countries, as these were primarily allocated to inland aquaculture and freshwater fisheries. Overall, we believe this methodology represents the general trend and distribution of oceans-related funding.

References

Preface

1. FAO*, The State of World Fisheries and Aquaculture 2016. Contributing to Food Security and Nutrition For All* (Rome: FAO, 2016), http://www.fao.org/3/a-i5555e.pdf.
2. Hoegh-Guldberg, O. et al., *Reviving the Ocean Economy: The Case for Action – 2015* (Gland, Switzerland: WWF International, 2015).

Executive Summary

1. Pauly, D. and D. Zeller, "Catch Reconstructions Reveal that Global Marine Fisheries Catches Are Higher than Reported and Declining," *Nature Communications* 7 (2016): 10244, doi: 10.1038/ncomms10244.

Marine conservation funding

Miguel Angel Jorge:

1. World Bank, *The Sunken Billions Revisited: Progress and Challenges in Global Marine Fisheries* (Washington, DC: World Bank, 2017), doi:10.1596/978-1-4648-0919-4.
2. Costello, Christopher et al., "Global Fishery Prospects Under Contrasting Management Regimes." *Proceedings of the National Academy of Sciences* 113, no. 18 (2016): 5125-29, doi: 10.1073/pnas.1520420113.

Marine fisheries and aquaculture

Dr. Boris Worm:

1. FAO, *State of World Fisheries.*
2. Lotze, H. K. and L. McClenachan, "Marine Historical Ecology: Informing the Future by Learning from the Past," in *Marine Community Ecology and Conservation,* ed. M.D. Bertness (Sinauer, 2013): 165-200.
3. Worm, B. and T.A. Branch, "The Future of Fish," *Trends in Ecology & Evolution* 27 (2012): 594-99.
4. Worm, B. et al., "Rebuilding Global Fisheries," *Science* 325 (2009): 578-85.
5. Selig, E.R. et al., "Global Priorities for Marine Biodiversity Conservation," PLoS ONE 9 (2014), e82898.
6. Costello, "Global Fishery Prospects."
7. Costello, C. et al., "Status and Solutions for the World's Unassessed Fisheries," *Science* 338 (2012): 517-20.
8. Worm, B. et al., "Impacts of Biodiversity Loss on Ocean Ecosystem Services," *Science* 314 (2006): 787-90.
9. Pauly, D. et al., "The Future for Fisheries," *Science* 302 (2003): 1359-61.
10. Mora, C. et al., "Management Effectiveness of the World's Marine Fisheries," *PLoS Biology* 7 (2009), e1000131.
11. Agnew, D. J. et al., "Estimating the Worldwide Extent of Illegal Fishing," PLoS ONE 4 (2009), e4570.
12. Pauly, "Catch Reconstructions," 10244.
13. Worm, B., "How to Heal an Ocean," *Nature* (2017) (forthcoming).
14. McCauley, D. J. et al., "Ending Hide and Seek at Sea," *Science* 351 (2016): 1148-50.
15. White, C. and C. Costello, "Close the High Seas to Fishing?," *PLoS Biology* 12 (2014), e1001826.
16. Sumaila, U. R., D. Zeller, R. Watson, J. Alder, and D. Pauly, "Potential Costs and Benefits of Marine Reserves in the High Seas," *Marine Ecology Progress* Series 345 (2007): 305-10.

Rear Admiral Jonathan White:

1. U.S. Department of State, "Illegal, Unreported, and Unregulated Fishing," accessed Mar. 21, 2017, https://www.state.gov/e/oes/ocns/fish/illegal/.
2. Ministry of Labour and Social Welfare, Lao People's Democratic Republic and UNICEF, *Broken Promises Shattered Dreams: A Profile of Child Trafficking in the Lao PDR,* accessed Mar. 21, 2017, https://www.unicef.org/media/files/BrokenPromisesFULLREPORT.pdf.
3. U.N. Security Council, "Letter Dated 12 July 2013 from the Chair of the Security Council Committee Pursuant to Resolutions 751 (1992) and 1907 (2009) Concerning Somalia and Eritrea Addressed to the President of the Security Council," http://www.securitycouncilreport.org/atf/cf/%7B65BFCF9B-6D27-4E9C-8CD3-CF6E4FF96FF9%7D/s_2013_413.pdf.
4. Urbana, Ian, "'Sea Slaves': The Human Misery that Feeds Pets and Livestock," *New York Times,* July 27, 2015.
5. *Ibid.*
6. FAO, *State of World Fisheries.*
7. Bergenas, Johan and Ariella Knight, *Secure Oceans: Collaborative Policy and Technology Recommendations for the World's Largest Crime Scene* (Stimson, Sept. 2016), https://www.stimson.org/sites/default/files/file-attachments/SecureOceans-Sep2016.pdf.
8. Bergenas, John and Ariella Knight, "How Illegal Fishing Threatens Development and Security," *World Politics Review,* Jan. 30, 2015, http://www.worldpoliticsreview.com/articles/14973/how-illegal-fishing-threatens-development-and-security.
9. Lybbert, Travis J. and Heather R. Morgan, "Lessons from the Arab Spring: Food Security and Stability in the Middle East and North Africa," in Food Security and Sociopolitical Stability, ed. Christopher B. Barrett (Oxford: Oxford University Press, 2013).
10. Lydia C. L. Teh and U. R. Sumaila, "Contribution of Marine Fisheries to Worldwide Employment," *Fish and Fisheries* 14 (Mar. 2013): 77-88, doi:10.1111/j.1467-2979.2011.00450.
11. Bearak, Max, "Somali Pirates Just Hijacked a Commercial Ship for the First Time in Five Years," *The Washington Post,* Mar. 14, 2017.
12. Monterey Bay Aquarium Seafood Watch, "Wild Seafood," accessed Mar. 21, 2017, http://www.seafoodwatch.org/ocean-issues/wild-seafood.
13. *Ibid.*
14. Illegal, Unreported, and Unregulated Fishing Enforcement Act of 2015, Pub. L. No. 114–81, 114th Cong., Nov. 5, 2015, https://www.congress.gov/114/plaws/publ81/PLAW-114publ81.pdf.
15. National Oceanic and Atmospheric Administration, "Recommendations of the Presidential Task Force on Combating Illegal, Unreported and Unregulated Fishing and Seafood Fraud," Fed. Reg. 79 (Dec. 18, 2014): 75536, https://www.federalregister.gov/documents/2014/12/18/2014-29628/recommendations-of-the-presidential-task-force-on-combating-illegal-unreported-and-unregulated.
16. *Oceana, One Name, One Fish: Why Seafood Names Matter,* accessed Mar. 21, 2017, http://usa.oceana.org/sites/default/files/4046/names_report_factsheet_final_high-res.pdf.

Marine Fisheries and Aquaculture narrative:

1. FAO Fisheries and Aquaculture Department, FishStatJ - *Software for Fishery Statistical Time Series,* updated July 21, 2016.
2. Costello, Christopher, "Fish Harder; Catch More?," *Proceedings of the National Academy of Sciences* 114, no. 7 (2017): 1442-44, doi:10.1073/pnas.1620731114.
3. Szuwalski, Cody S., Matthew G. Burgess, Christopher Costello, and Steven D. Gaines, "High Fishery Catches Through Trophic Cascades in China," Proceedings of the National Academy of Sciences, 114 no. 4 (2017): 717-21, doi:10.1073/pnas.1612722114/-/DCSupplemental.
4. Watson, R.A., *Global Fisheries Landings* V2.0 (Nov. 14, 2016), doi:10.4226/77/58293083b0515.
5. FAO, *State of World Fisheries.*
6. Pauly D. and D. Zeller, eds., Sea Around Us Concepts, Design and Data, 2015, seaaroundus.org.
7. Pauly, "Catch Reconstructions," 10244.
8. Szuwalski, "Trophic Cascades."
9. *Ibid.*
10. World Bank, *"Sunken Billions Revisited,"* 47-63.
11. Szuwalski, "Trophic Cascades."
12. *Ibid.*
13. World Bank, *"Sunken Billions Revisited,"* 47-63.
14. Costello, "Fish Harder; Catch More?," 1442-44.
15. Melnychuk, Michael C., Emily Peterson, Matthew Elliott, and Ray Hilborn, "Fisheries Management Impacts on Target Species Status," Proceedings of the National Academy of Sciences 114, no. 1 (2016): 178-83, doi:10.1073/pnas.1609915114.
16. CEA, *Ocean Prosperity Roadmap: Fisheries and Beyond. A Synthesis Report on the Economic and Biological Upside of Fisheries Reform to Unlock the Value of the Ocean,* 2015, https://www.oceanprosperityroadmap.org/wp-content/uploads/2015/05/6.-Country-Level-Costs-vs.-Benefits-Fishery-Management-Report-5-26-15A.pdf.
17. Phillips, M., P.J.G. Henriksson, N. Tran, C.Y. Chan, C.V. Mohan, U-P Rodriguez, S. Suri, S. Hall, and S. Koeshendrajana, *Exploring Indonesian Aquaculture Futures* (Penang, Malaysia: WorldFish, 2015): 2015-39.
18. *Ibid.*
19. FAO, *State of World Fisheries.*
20. World Bank, *Fish to 2030: Prospects for Fisheries and Aquaculture,* World Bank Report Number 83177-GLB, Dec. 2013.
21. *Ibid.*
22. *Ibid.*

Impacts of climate change

Dr. Ove Hoegh-Guldberg:

1. IPCC, "Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change," in *Climate Change* 2014: Synthesis Report, ed. Pachauri et al., (Geneva, Switzerland: IPCC, 2014): 151.
2. Hoegh-Guldberg et al., "The Ocean," in *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change,* ed. Barros et al. (Cambridge, United Kingdom and New York: Cambridge University Press, 2014): 1655-1731.
3. Hoegh-Guldberg, O. and J. Bruno, "The Impact of Climate Change on the World's Marine Ecosystems," *Science* 328 (2010): 1523-28.
4. Hoegh-Guldberg, "The Ocean."
5. Poloczanska, E.S., et al., "Global Imprint of Climate Change on Marine Life," *Nature Climate Change* 3.10 (2013): 919-25.
6. Frieler, K., et al., "Limiting Global Warming to 2oC Is Unlikely to Save Most Coral Reefs," *Nature Climate Change* 3.2 (2013): 165-70.
7. Paris Climate Change Agreement, 2015, http://unfccc.int/paris_agreement/items/9485.php.

Dr. William Cheung:

1. Hausfather, Z., K. Cowtan, D. Clarke, P. Jacobs, M. Richardson, and R. Rohde, "Assessing Recent Warming Using Instrumentally Homogeneous Sea Surface Temperature Records," Science Advances 3, no. 1 (2017), http://advances.sciencemag.org/content//1/e1601207.
2. Poloczanska, "Global Imprint."
3. Guattuso, J.P., A. Magnan, R. Billé, W.W.L. Cheung, E.L. Howes, F. Joos, D. Allemand, L. Bopp, S. Cooley, C.M. Eakin, O. Hoegh-Guldberg, R.P. Kelly, et al., "Contrasting Futures for Ocean and Society from Different CO2 Emissions Scenarios," Science 349 (2015): 6243, aac4722.
4. Jones, M.C. and W.W.L. Cheung, "Multi-Model Ensemble Projections of Climate Change Effects on Global Marine Biodiversity," ICES Journal of Marine Science 72 (2015): 741-52.
5. Lam, V.W.Y., W.W.L. Cheung, and U.R. Sumaila, "Marine Capture Fisheries in the Arctic: Winners or Losers Under Climate Change and Ocean Acidification?," Fish and Fisheries (2016): 335-57.
6. Cheung, W.W.L., R. Watson, and D. Pauly, "Signature of Ocean Warming on Global Marine Fisheriesm" Nature 497 (2013): 365-68.
7. Britten, G.L., M. Dowd, and B. Worm, "Changing Recruitment Capacity in Global Fish Stocks," Proceedings of the National Academy of Sciences 113 (2016): 134-39.
8. Cheung, W.W.L., G. Reygondeau, and T.L. Frolicher, "Large Benefits to Marine Fisheries of Meeting the 1.5°C Global Warming Target," Science 354 (2016): 1591-94.
9. Lam, W.W.L., W. Cheung, G. Reygondeau, and R. Sumaila, "Projected Change in Global Fisheries Revenues Under Climate Change," Scientific Reports 6 (2016): 32607-15.
10. Golden, C. et al., "Nutrition: Fall in Fish Catch Threatens Human Health," Nature 534 (2016): 317-20, doi:10.1038/534317a.
11. Hughes, K.M., L. Dransfeld, and M.P. Johnson, "Climate and Stock Influences on the Spread and Locations of Catches in the Northeast Atlantic Mackerel Fishery," Fisheries Oceanography 24, no. 6 (2015): 540-52.
12. Pershing et al., "Slow Adaptation in the Face of Rapid Warming Leads to Collapse of the Gulf of Maine Cod Fishery," Science 350 (2015): 809-12.
13. Ibid.
14. Pinnegar, J.K., G.H. Engelhard, M.C. Jones, W.W.L. Cheung, M.A. Peck, A.D. Rijnsdorp, and K.M. Brander, "Socio-economic Impacts—Fisheries," in North Sea Region Climate Change Assessment (Springer, 2016): 375-95.

Climate Change narrative:

1. Magnan, A.K. et al., *Intertwined Ocean and Climate: Implications for International Climate Negotiations* (IDDRI, 2015): 4.
2. *Ibid.*
3. IPCC, *Climate Change 2014: Synthesis Report,* 151.
4. Magnan, A.K. et al., "Implications of the Paris Agreement for the Ocean," *Nature Climate Change* 6 (2016): 732-35.
6. *Ibid.*
7. Laffoley, D. and J.M. Baxter, eds., *Explaining Ocean Warming: Causes, Scale, Effects and Consequences.Full Report* (Gland, Switzerland: IUCN, 2016): 456.
8. *Ibid.*
9. *Ibid.*
10. IPCC, *Climate Change 2014: Synthesis Report,* 151.
11. *Ibid.*
12. *Ibid.*
13. Magnan, "Implications of the Paris Agreement."
14. *Ibid.*
15. Rodgers, K.B., J. Lin, and T.L. Frölicher, "Emergence of Multiple Ocean Ecosystem Drivers in a Large Ensemble Suite With an Earth System Model," Biogeosciences 12, no. 11 (2015): 3301-20.
16. AMAP, *Snow, Water, Ice and Permafrost. Summary for Policy-makers* (Oslo: Arctic Monitoring and Assessment Programme, 2017): 20.
17. *Ibid.*
18. *Ibid.*
18. *Ibid.*
19. *Ibid.*
20. Hope, C. and K. Schaefer, "Economic Impacts of Carbon Dioxide and Methane Released from Thawing Permafrost," *Nature Climate Change* 6 (2016): 56-59, doi:10.1038/nclimate2807.
21. Hoegh-Guldberg, *Reviving the Ocean Economy.*
22. *Ibid.*
23. *Ibid.*
24 Laffoley, *Explaining Ocean Warming,* 456.
25. *Ibid.*
26. Climate Council of Australia Limited, *Climate Change: A Deadly Threat to Coral Reefs,* 2017, https://uploads.guim.co.uk/2017/04/11/CC_Report_1.pdf.
27. Lam, "Projected Change in Global Fisheries Revenues."
28. Poloczanska, "Global Imprint."
29. Cheung, W.W.L., *Climate Change Effects on Illegal, Unreported, and Unregulated Fishing,* Feb. 22, 2016, http://www.nereusprogram.org/climate-change-effects-on-illegal-unreported-and-unregulated-fishing/.
30. Cheung W.W.L., J.L. Sarmiento, J. Dunne, et al., "Shrinking of Fishes Exacerbates Impacts of Global Ocean Changes on Marine Ecosystems," *Nature Climate Change* 3 (2013): 254-58.
3 Lam, "Marine Capture Fisheries in the Arctic."
32. *Ibid.*
33. Lam, "Projected Change in Global Fisheries Revenues."
34. *Ibid.*
35. Golden, "Fall in Fish Catch."
36. *Ibid.*
37. Magnan, "Implications of the Paris Agreement."
38. *Ibid.*
39. *Ibid.*
40. *Ibid.*
41. IPCC, *Climate Change 2014: Synthesis Report,* 151.
42. Nereus Program, "1.5°C Paris Agreement Target Could Net Six Million Tonnes of Fish Annually," Dec. 22, 2016, http://www.nereusprogram.org/1-5c-paris-agreement-target-could-net-six-million-tonnes-of-fish-annually/.

Land-based and industrial pressures

1. Crain, C., B.S. Halpern, M.W. Beck, and C.V. Kappel, "Understanding and Managing Human Threats to the Coastal Marine Environment," *The Year in Ecology and Conservation Biology* (2009) 1162: 39-62.
2. Halpern, B.S., M. Frazier, J. Potapenko, K.S. Casey, K. Koenig, C. Longo, J.S. Lowndes, R.C. Rockwood, E.S. Selig, K.A. Selkoe, and S. Walbridge, "Spatial and Temporal Changes in Cumulative Human Impacts on the World's Ocean," *Nature Communications* 6 (2015): 7615.
3. Polidoro, B.A., K.E. Carpenter, L. Collins, N.C. Duke, A.M. Ellison, et al., "The Loss of Species: Mangrove Extinction Risk and Geographic Areas of Global Concern," *PLoS ONE* 5 no. 4 (2010): e10095.
4. Valiela, I., et al., *"Global Losses of Mangroves and Salt Marshes," in Global Loss of Coastal Habitats: Rates, Causes, and Consequences,* ed. C.M. Duarte (Fundacion BBVA, 2009).
5. Tian, B., W. Wu, Z. Yang, and Y. Zhou, "Drivers, Trends, and Potential Impacts of Long-Term Coastal Reclamation in China from 1985 to 2010," *Estuarine, Coastal and Shelf Science* (2016) 170: 83-90.
6. *Ibid.*
7. *Ibid.*
8. Polidoro, "Mangrove Extinction Risk."
9. Asa, S. and S. Minnemeyer, "Satellite Data Reveals State of the World's Mangrove Forests," World Resources Institute, Feb. 20, 2015, http://www.wri.org/blog/2015/02/satellite-data-reveals-state-world%E2%80%99s-mangrove-forests.
10. *Ibid.*
11. UNEP, *The Importance of Mangroves to People: A Call to Action,* eds. J. van Bochove, E. Sullivan, and T. Nakamura (Cambridge: UNEP World Conservation Monitoring Centre, 2014).
12. Ibid.
13. AGU, "Press Release: Worldwide Ship Traffic Up 300 Percent Since 1992," Nov. 17, 2014, https://news.agu.org/press-release/worldwide-ship-traffic-up-300-percent-since-1992/.
14. AIS is a technology designed to avoid collisions at sea and is required on most large vessels. A vessel broadcasts its location every 2 to 20 seconds while moving and every 3 to 6 minutes while anchored. These signals notify nearby boats and ships of the vessel's location. The International Maritime Organization's International Convention for the Safety of Life at Sea requires AIS to be fitted aboard international voyaging ships with gross tonnage (GT) of 300 or more, and all passenger ships regardless of size. Many countries have adopted the IMO regulations or stricter ones for their Exclusive Economic Zones.
15. Lloyd's, Climate Wise, and Chatham House, *Arctic Opening: Opportunity and Risk in the High North* (2012), https://www.lloyds.com/~/media/files/news%20and%20insight/360%20risk%20insight/arctic_risk_report_webview.pdf.
16. *Ibid.*

17. Struzik, Ed, "Shipping Plans Grow as Arctic Ice Fades," Yale e360, Nov. 17. 2016, http://e360.yale.edu/features/cargo_shipping_in_the_arctic_declining_sea_ice.
18. *Ibid.*
19. Diaz, R. J., and R. Rosenberg, "Spreading Dead Zones and Consequences for Marine Ecosystems," *Science* 321 (2008): 926-29.
20. *Ibid.*
21. *Ibid.*
22. *Ibid*.
23. Jernelöv A., "The Threats from Oil Spills: Now, Then, and in the Future," 39(5-6) Ambio (2010): 353-66, doi:10.1007/s13280-010-0085-5.
24. *Ibid.*
25. Crain, "Understanding and Managing Human Threats."
26. Jepson, P. and R.J. Law, "Persistent Pollution, Persistent Threats," *Science* 352 (2016): 6292.
27. Stemmler, I. and G. Lammel, "Cycling of DDT in the Global Environment 1950-2002: World Ocean Returns the Pollutant," *Geophyscial Research Letters* 36 (2009).
28. *Ibid.*
29. Jambeck, J., R. Geyer, C. Wilcox, T.R. Siegler, et al., "Plastic Waste Inputs from Land into the Ocean," Science 347 (2015): 768-71.
30. Cozar, A. et al., "Plastic Debris in the Open Ocean," *Proceedings of the National Academies of Science* 111 (2015): 10239-44.
31. Van Sebille E., C. Wilcox, L. Lebreton, N. Maximenko, B.D. Hardesty, J.A. Van Franeker, M. Eriksen, D. Siegel, F. Galgani, K.L. Law, et al., "A Global Inventory of Small Floating Plastic Debris," *Environmental Research Letters* 10 (2015): 124006.
32. Schuyler et al., "Risk Analysis Reveals Global Hotspots for Marine Debris Ingestion by Sea Turtles," *Global Change Biology,* 2 (2016): 567-76.
33. Wilcox, C. et al., "Threat of Plastic Pollution to Seabirds is Global, Pervasive and Increasing," *Proceedings of the National Academies of Science* 112 (2015): 11899-904.
34. Woodall, L.C. et al., "The Deep Sea is a Major Sink for Microplastic Debris," *Royal Society Open Science* (2014): 1.
35. Rochman, C.M. et al., "Anthropogenic Debris in Seafood: Plastic Debris and Fibers from Textiles in Fish and Bivalves Sold for Human Consumption," *Scientific Reports* (2015): 5.
36. Van Cauwenberghe L., M. Claessens, M.B. Vandegehuchte, and C.R. Janssen, "Microplastics Are Taken up by Mussels (Mytilus edulis) and Lugworms (Arenicola marina) Living in Natural Habitats," *Environmental Pollution* 199 (2015): 10-17.
37. Browne, M.A., et al., "Accumulation of Microplastic on Shorelines Worldwide: Sources and Sinks," *Environmental Science and Technology* 45 (2011): 9175-79.
38. Hartline, N.L., N.J. Bruce, S.N. Karba, E.O. Ruff, S.U. Sonar, and P.A. Holden, "Microfiber Masses Recovered from Conventional Machine Washing of New or Aged Garments," *Environmental Science Technology* (2016): 50.
39. World Economic Forum, The New Plastics Economy: Rethinking the Future of Plastics, 2016, http://www3.weforum.org/docs/WEF_The_New_Plastics_Economy.pdf.
40. *Ibid.*
41. Jambeck, J., R. Geyer, C. Wilcox, T.R. Siegler, et al., "Plastic Waste Inputs from Land into the Ocean," *Science* 347 (2015): 768-71.
42. *Ibid*.

Marine Protected Areas (MPAs)

Anne Walton:

1. Blamford, A., P. Gravestock, N. Hockley, C. McClean, and C. Roberts, "The Worldwide Costs of Marine Protected Areas," Proceedings of the National Academies of Science 101, no.26 (2004): 9696.
2. Our Ocean Conference, Department of State Bureau of Oceans and International Environment and Scientific Affairs, http://ourocean2016.org/commitments/#commitments-main.
3. UNEP-WCMC and IUCN, Protected Planet Report 2016 (Cambridge, United Kingdom and Gland, Switzerland: UNEP-WCMC and IUCN, 2016), referencing the World Data Base on Protected Areas (WDPA), https://www.iucn.org/theme/protected-areas/our-work/world-database-protected-areas.

MPA Narrative:

1. IUCN and UNEP-WCMC, *The World Database on Protected Areas* (WDPA) (Cambridge, United Kingdom: UNEP-WCMC, 2015), www.protectedplanet.net.
2. Marine Conservation Institute, MPAtlas (Seattle, 2017), www.mpatlas.org.
3. Ocean Unite and Marine Conservation Institute, *Case Study: The Arctic. An Opportunity in the Making?* (Washington, DC, Oct. 2016): 5-7.
4. Brander, L., C. Baulcomb, J.A.C. van der Lelij, F. Eppink, A. McVittie, L. Nijsten, and P. van Beukering, *The Benefits to People of Expanding Marine Protected Areas* (WWF, 2015), http://assets.wnf.nl/downloads/mpa_rapport_volledig.pdf.
5. UNEP-WCMC and IUCN, *Protected Planet Report* 2016.
6. *Ibid.*
7. Ocean Unite and Marine Conservation Institute, "Case Study: National Waters."

the David & Lucile Packard FOUNDATION

The David and Lucile Packard Foundation is a private family foundation created in 1964 by David Packard (1912–1996), cofounder of the Hewlett-Packard Company, and Lucile Salter Packard (1914–1987). The Foundation provides grants to nonprofit organizations in the following program areas: Conservation and Science; Population and Reproductive Health; Children, Families, and Communities; and Local Grantmaking. The Foundation makes national and international grants and also has a special focus on the Northern California counties of San Benito, San Mateo, Santa Clara, Santa Cruz and Monterey. Today, the Packard Foundation's ocean investments are focused in six countries and on a suite of global strategies that together offer great potential for accelerating positive change. Learn more at www.packard.org.

CEA California Environmental Associates

Since 1984, California Environmental Associates (CEA) has supported the work of environmental foundations and nonprofits as well as sustainability-oriented businesses with in-depth research and analysis, program design and evaluation, and strategic planning. Learn more at www.ceaconsulting.com.