Commissioned by

HIGH LEVEL PANEL for
A SUSTAINABLE
OCEAN ECONOMY

Ocean Solutions That Benefit People, Nature and the Economy

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About the High Level Panel for a Sustainable Ocean Economy

The High Level Panel for a Sustainable Ocean Economy (Ocean Panel) is a unique initiative by 14 world leaders who are building momentum for a sustainable ocean economy in which effective protection, sustainable production and equitable prosperity go hand in hand. By enhancing humanity's relationship with the ocean, bridging ocean health and wealth, working with diverse stakeholders and harnessing the latest knowledge, the Ocean Panel aims to facilitate a better, more resilient future for people and the planet.

Established in September 2018, the Ocean Panel has been working with government, business, financial institutions, the science community and civil society to catalyse and scale bold, pragmatic solutions across policy, governance, technology and finance to ultimately develop an action agenda for transitioning to a sustainable ocean economy. Co-chaired by Norway and Palau, the Ocean Panel is the only ocean policy body made up of serving world leaders with the authority needed to trigger, amplify and accelerate action worldwide for ocean priorities. The Ocean Panel comprises members from Australia, Canada, Chile, Fiji, Ghana, Indonesia, Jamaica, Japan, Kenya, Mexico, Namibia, Norway, Palau and Portugal and is supported by the UN Secretary-General's Special Envoy for the Ocean.

The Ocean Panel's approach is both ambitious and practical. Collaborative partnerships are essential to converting knowledge into action. To develop a common understanding of what a sustainable ocean economy looks like, the Ocean Panel gathers input from a wide array of stakeholders, including an Expert Group and an Advisory Network. The Secretariat, based at World Resources Institute, assists with analytical work, communications and stakeholder engagement.

About This Report

This report lays out the contours of a new relationship between the ocean and humanity. Like any relationship, it is reciprocal: it considers the care required as well as the rewards returned. It departs from a conservation philosophy of 'minimising destruction' and showcases a balanced model that simultaneously achieves effective ocean protection, sustainable production and equitable prosperity.

This work has been commissioned as an input to the Ocean Panel. The report builds on the latest scientific research, analyses and debates from around the world—including the insights from 16 Blue Papers and 3 special reports commissioned by the Ocean Panel: 'The Ocean as a Solution to Climate Change: Five Opportunities for Action', 'A Sustainable and Equitable Blue Recovery to the COVID-19 Crisis' and 'A Sustainable Ocean Economy for 2050: Approximating Its Benefits and Costs'. The report has also been informed by ideas emerging during Ocean Panel deliberations and consultations with a wide range of individuals, organisations and entities.

The report has benefitted from a robust peer review process involving more than 20 experts from all over the globe. It seeks to synthesise science-based information and identify options the Ocean Panel may wish to consider and share broadly. However, by design it is not policy-prescriptive but rather presents options for action by policymakers and other key actors. Ultimately, this report is an independent input to the Ocean Panel process and does not necessarily represent the thinking of the Ocean Panel.

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Contents

How to Use This Report

This report can be read like a book, 'cover to cover'—the reader will follow a narrative arc which balances hope and concern, present and future states, concrete examples and more abstract ideas.

However, it is more probable that this report will be used like a readily accessible compendium of the latest scientific insights, frameworks and ideas that allow readers to find specific facts, messages or concepts and dive deeper on selected sections of the report.

This report aims at answering three core questions:

- **WHY**: Why do we need a sustainable ocean economy and why now? (Chapter 1)
- **WHAT**: What would a sustainable ocean economy look like? What would be the main economic components and the interlinkages between them? What would be the benefits to expect for the economy, the people and the planet? (Chapter 2)
- **HOW**: How should such a complex socioeconomic transition be apprehended? How should a 10-year transformation agenda be structured? How should we get started? (Chapter 3)

Readers looking for arguments about the need for a sustainable ocean economy and reasons for hope about the possibility of one should read the prologue and Chapter 1.

Readers who want to understand what a sustainable ocean could look like in 2050, and the expected associated benefits, should read Chapter 2.

Ocean practitioners already familiar with the concept of a sustainable ocean economy are invited to go straight to Chapter 3 to discover a fresh and practical approach to guide the transition to a sustainable ocean economy. In particular, Section 3.2 presents an 'ocean action agenda' that could be used as a handbook to help decision-makers structure their sustainable ocean economy program, be it at a state or a company level.

This handbook identifies a number of key actions for each area of focus, covering both cross-cutting enablers and ocean-based sectors. Finally, Section 3.3 suggests some very concrete ideas that could be implemented immediately to start or accelerate the implementation of the more holistic, 10-year, ocean action agenda.

Foreword

As heads of government from ocean states, we know the ocean and its value.

Even so, the ocean keeps providing us with new insights.

From this report we learn that the ocean is even more important than we thought: for human and planetary health, for climate and food security, for local jobs and the global economy.

We learn that ocean health is more at risk than we thought, because different pressures add up and contribute to rapid and unpredictable changes in ocean ecosystems.

But importantly, we also learn that the ocean holds many of the urgent solutions humanity and the planet need. More fish and seafood production can provide abundant climate-friendly proteins for a growing population. Offshore clean energy can power the world many times over. Mangroves and seaweed can provide food, fuel and fibre while mitigating climate change and boosting biodiversity. Genetic resources in the ocean can advance health and fight disease.

Here's the lesson:

We *can* and we *must* produce more from the ocean, and we have to do it in ways that mitigate climate change, preserve biodiversity, regenerate ocean health and leave no one behind. We can produce more, by protecting more. The report gives us confidence in that possibility. But the report also teaches us how we have to rethink ocean policy and management altogether.

We must approach ocean management in an integrated manner in order to achieve the vision of protection, production and prosperity. We need a comprehensive approach to sustainably manage 100 percent of the ocean.

This report – building on a wide range of "Blue Papers" and "Special Reports" – is the responsibility of experts invited to inform the deliberations of the Ocean Panel. We wish to thank the global group of more than 250 experts for providing this impressive volume of knowledge.

As co-chairs of the Ocean Panel, we have brought 14 presidents and prime ministers together committed to sustainable ocean management and transformational policies that meet the test the report puts forward: protecting, producing and prospering from the ocean.

Jointly, the Ocean Panel countries are embarking on this ambitious journey, with 2030 and the accomplishment of the UN Sustainable Development Goals as our horizon. We invite more leaders and people to join.

Erna Solberg
Prime Minister of Norway

Tommy Remengesau, Jr.
President of Palau

EXECUTIVE SUMMARY

The New Ocean Narrative

Billions of people have personal connections to the ocean. For many people living in coastal communities, the ocean is not only a source of food and livelihoods, it is an intrinsic part of their culture and heritage. For the millions of people who earn their living from the ocean, it is a source of income and a way of life. For the 40 percent of the world's population that live within 150 kilometres of the coast and the hundreds of millions of others who visit it, the ocean is central to their lives[1]. The ocean plays an essential and usually unrecognised role in the daily lives of all of the planet's inhabitants. Indeed, breathing itself would be impossible without the ocean, which produces half of the earth's oxygen[2].

The ocean is also an enormous economic asset. Around 90 percent of the world's goods are traded across the ocean[3]. Hundreds of millions of people work in fishing and mariculture, shipping and ports, tourism, offshore energy, pharmaceuticals and cosmetics—all of which rely on resources a healthy ocean can offer the ocean[4]. By some estimates, the ocean economy directly contributes more than $1.5 trillion a year to the global economy[5].

Putting a resource this critical at risk is reckless. But the world has not handled the ocean with care. Poor management has damaged many of the ocean's assets and reduced the ocean's natural ability to restore itself. Ocean health is on a downward spiral, preventing humanity from reaping the riches a healthy ocean could produce and jeopardising the future. The ocean is becoming warmer, more acidic, stormier, higher, more oxygen-depleted, less predictable and less resilient—and neither the problems it is facing nor the wealth it yields are distributed equitably.

Climate change is disproportionately affecting vulnerable and marginalised people, many of whom depend on the ocean for nutrition, identity and income. As they battle a warming ocean and rising sea level, they increasingly face depleted and shifting fish stocks without the ability to change gear or travel further to fish or seek other sources of livelihood.

For years, the overarching view was that the ocean is so vast that it is simply too big to fail. The folly of this approach is now evident. The new dominant narrative is that the problems are so complex that the ocean is simply too big to fix. This view is also incorrect. The ocean's problems are real, but action is already taking place to solve them.

A new way of thinking has immense potential to open the door to a sustainable ocean economy. This approach abandons the false choice between economic development and environmental protection. In contrast to a 'conservation philosophy' of minimising destruction or an 'extractive approach' of maximising the resources that can be extracted from the ocean, the new approach seeks to achieve the integration of the 'three Ps' of effective protection, sustainable production and equitable prosperity. This approach does not mean just leaving the ocean alone; it means proactively managing human activities to use the ocean wisely rather than using it up, in order to help build a much richer future in which people have more wealth and better health, nature thrives and resources are distributed more equitably.

Realising the new vision requires an integrated, rather than a sectoral, approach that is based on five building blocks:

- Using science and data to drive decision-making
- Engaging in goal-oriented ocean planning
- De-risking finance and using innovation to mobilise investment
- Stopping land-based pollution
- Changing ocean accounting so that it reflects the true value of the ocean

Putting these building blocks in place would enable change across the entire ocean economy, not just in specific sectors or locations. Over time, sustainable ocean management could help the ocean produce as much as 6 times more food and generate 40 times more renewable energy than it currently does[6], contribute one-fifth of the reductions in greenhouse gas emissions needed to keep the world within the 1.5°C temperature rise limit set by the Paris Agreement goals by 2050[7], help lift millions of people out of poverty, improve equity and gender balance, increase economic and environmental resilience, build the industries of the future and provide low-carbon fuel and feed for activities on land.

Investments in a sustainable ocean economy are not just good for the ocean. They represent an excellent business proposition. Investing $2.8 trillion today in just four ocean-based solutions—offshore wind production, sustainable ocean-based food production, decarbonisation of international shipping, and conservation and restoration of mangroves—would yield a net benefit of $15.5 trillion by 2050, a benefit-cost ratio of more than 5:1[8].

The ocean is so vast, and its role in the global economy and the lives of the world's people so fundamental, that it can be difficult to know where to start in creating a sustainable ocean economy. Fortunately, pragmatic solutions are already being implemented, albeit not at the scale needed. These efforts could jump-start progress on a much larger scale, putting the world on a trajectory that would vastly increase prosperity in the coming decade and the longer term. These approaches embrace a philosophy in which stakeholders—including direct users of the ocean (fishers, shippers, energy producers and beach lovers, among others) as well as policymakers, governments, businesses and others—accept the new paradigm and work together to achieve the same goal of a healthy, productive ocean.

Some of the most promising efforts include empowering communities and modifying incentives to align economic and conservation outcomes. In the Philippines, for example, a network has been created that grants fishing communities clear, exclusive rights to fish in certain areas. In communities that organised to manage 'their' fishing areas and protected zones, boats and fishers are registered, the catch is recorded, regulations are respected and fishers participate in management. By embracing sustainability, participating communities increased their food and financial security and gained access to new markets and sources of capital—improving their own well-being while protecting the ocean. Complementary global trends are also emerging. Open data networks are making it easier to track and detect illegal fishing vessels. Governments are starting to tackle plastic pollution, and financiers are starting to recognise the value of investing in the ocean.

Practical solutions that can be implemented at a modest scale as well as high-level actions could create a sustainable ocean economy, underpinned by the three Ps of effective protection, sustainable production and equitable prosperity. Implementing them requires political will at all levels, including the very top.

The ocean is not too big to fail, and it is not too big to fix. But it is too big to ignore. The more we learn about the ocean, the more we see that it is central to improving the health, wealth and well-being of people. It holds the answers to the most pressing challenges facing humanity, including climate change and food security. It is time to shift away from thinking of the ocean as a victim toward seeing it as an essential part of the solution to global challenges. New partnerships need to be forged that will take action now to achieve a sustainable ocean and a sustainable future. The choice is not between ocean protection and production. Together they can help build a healthy and prosperous future.

The Health, Wealth and Well-Being of the World and Its People Depend on the Ocean

Maintaining a healthy ocean is vital to improving global health and increasing global prosperity for everyone; expanding opportunities for all people, including women and marginalised groups; and making the world a better place to live for all, even people living far from the ocean. A sustainable ocean economy is obviously important for the traditional ocean sectors, such as fisheries and shipping. But its value goes well beyond the lives of people whose income comes directly from the sea. Because of the interconnectedness of the global economy, what happens in the ocean affects not only fishers in Fiji but also farmers in Zimbabwe, whose imported tools may have travelled to Africa in a container ship and whose air quality and climate are affected by what happens in the ocean.

The ocean provides a wide variety of vital benefits, many of which are often overlooked:

- **It helps make the planet liveable and is critical to managing the effects of climate change.** The ocean produces half of the planet's oxygen, absorbs 93 percent of the world's anthropogenic heat and moderates the earth's temperature by reducing the heat differential between the poles and the Equator[9]. Without the ocean's regulation of the earth's climate, much more carbon dioxide would be trapped in the atmosphere, exacerbating global climate change[10].
- **The global economy and the livelihoods of hundreds of millions of people depend on the ocean.** The modern global economy could not exist without the ocean. Around 90 percent of all internationally traded goods travel by ship[11]. The ocean economy directly contributes an estimated $1.5 trillion to the global economy[12]. The ocean food sector alone provides up to 237 million jobs, including in fishing, mariculture and processing[13]. Millions of people also work in other ocean sectors, including shipping, ports, energy and tourism—and many more are indirectly connected to the ocean economy.
- **The ocean provides billions of people with nutritious food, with a much smaller environmental footprint than land-based food production.** More than 3 billion people rely on food from the sea as a source of protein and key nutrients, including omega-3 fatty acids and iodine[14].

- **Coastal habitats, such as mangroves, provide protection for hundreds of millions of people, nurture biodiversity, detoxify pollutants flowing off the land, and provide nursery areas for fisheries, increasing the supply of food and providing livelihoods.** They are also a source of revenue. Coral reefs alone contribute $11.5 billion a year to global tourism, benefitting more than 100 countries and providing food and livelihoods to local people[15].
- **The ocean provides a sense of wonder, solace and connection to the natural world and is deeply woven into the cultural and spiritual lives of billions of coastal dwellers**. It also gives pleasure to the hundreds of millions of people a year who visit it[16].
- **The ocean may store unknown treasures**. In addition to its known benefits, it may be the home of undiscovered resources—including medical ones—and new knowledge.

Its Potential Is Enormous, but the Ocean Is in Trouble

Human stressors affect virtually the entire ocean, making it more difficult for the ocean to sustain human life on earth. Climate change, overfishing, habitat destruction, biodiversity loss, excessive nutrient loads, pollution and other problems are damaging the ocean's health.

- **Climate change and greenhouse gas emissions are having multiple effects on the ocean**. The ocean is becoming warmer and more acidic, putting pressure on plants and animals from the base of the ocean food web to the top. Ocean warming affects circulation, stratification, oxygen content and sea level. By 2100, as many as 630 million people could be at risk of coastal flooding caused by climate change[17]. Sea level rise also affects agriculture, by submerging land, salinising soil and groundwater, and eroding coasts. It will also erode and submerge tourism infrastructure and beaches. In the Caribbean, for example, sea level rise of 1 metre is projected to endanger up to 60 percent of resorts, damage or cause the loss of 21 airports and severely flood 35 ports[18]. Rebuilding the region's resorts alone is projected to cost the Caribbean $10–$23 billion in 2050[19].
- **Habitats are being destroyed, biodiversity is declining and the distribution of species is changing—all of which reduce the benefits that ocean ecosystems provide**. Coastal habitats are disappearing at an alarming rate. Global mangrove cover declined by 25–35 percent between 1980 and 2000, largely as a result of land development and conversion to unsustainable mariculture ponds and rice paddies[20]. The loss of coastal habitats and coral reefs is eroding natural coastal protection, exposing 100–300 million people living within coastal 100-year flood zones to increased risk of floods and hurricanes[21]. Coral reefs—virtually all of which will be lost at 2°C warming—are declining rapidly as a result of compounding pressures from rising ocean temperatures, overfishing and nutrient pollution[22]. The biodiversity of the open ocean declined by up to 50 percent over the past 50 years[23], and the relative abundance of different species has shifted in favour of species that are more tolerant of low-oxygen conditions, such as microbes, jellyfish and some squid[24].
- **Plastic, other land-based pollutants and discharge from ships contaminate the ocean**. Because of the common belief that 'the solution to pollution is dilution', the ocean has long been used as a repository for sewage, nutrient run-offs, heavy metals, nuclear waste, persistent toxicants, pharmaceuticals, personal care products and other noxious items. More than 80 percent of all marine pollution originates on land[25]. Millions of metric tons of plastic are dumped into the ocean every year, entangling, sickening and contaminating at least 700 species of marine life[26]. Untreated ballast water from ships is discharged into foreign ports, creating one of the principal vectors of potentially invasive alien species[27].
- **Overfishing is depleting fish stocks and harming wildlife**. The 'tragedy of the ocean commons' open access that characterises fishing in many parts of the ocean means that too many boats pursue too few fish, at the expense of overall system health and productivity. Exacerbated by subsidies that increase the capacity of the fishing fleet and by illegal, unreported and unregulated (IUU) fishing, fishing has become the number one driver of extinction risk for marine vertebrates (excluding birds)[28]. If overfishing continues, annual yield is projected to fall by over 16 percent by 2050, threatening global food security[29].

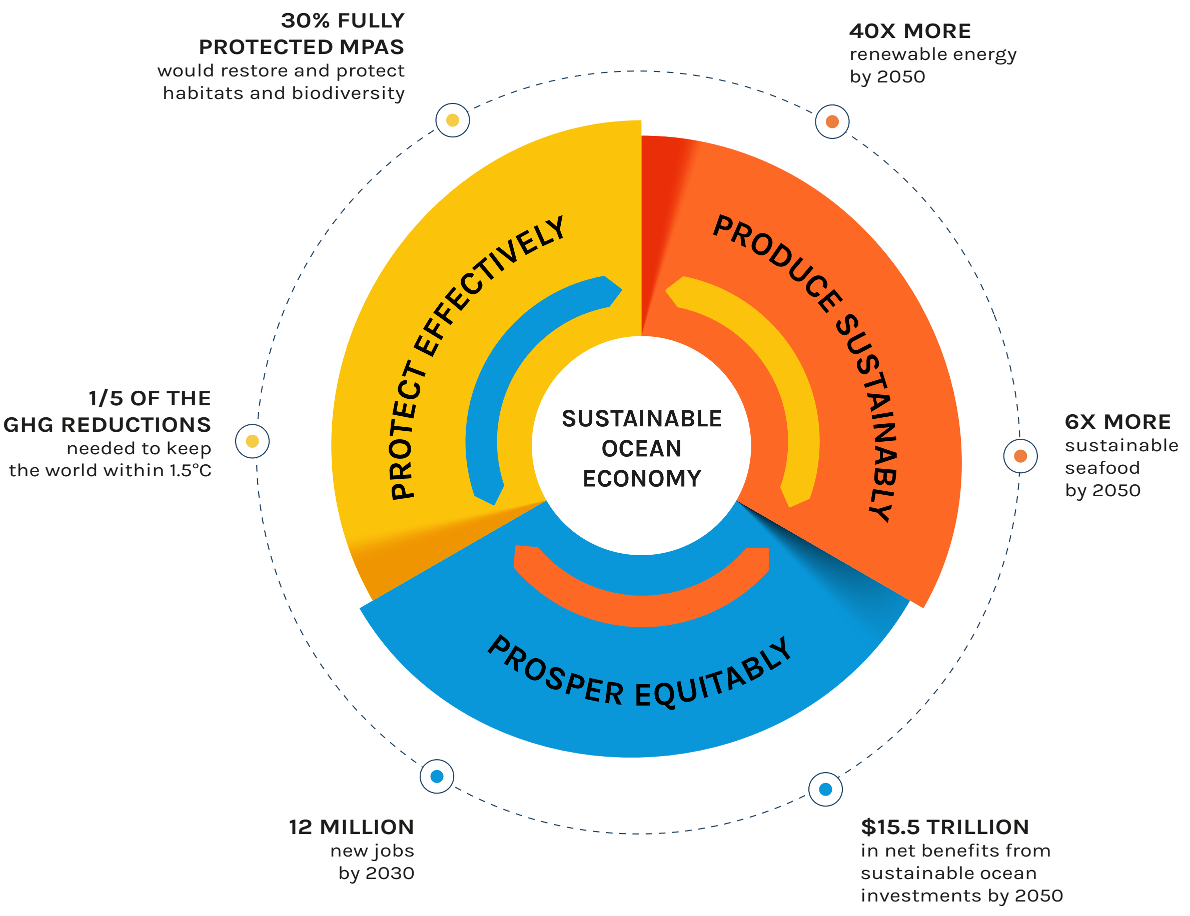
A single stressor, such as overfishing or pollution, can do considerable damage. Worse still, individual stressors locally compound one another, with enormous consequences for ecosystems. Without action, these problems could cost the global economy more than $400 billion a year by 2050. By 2100, the annual cost could reach $2 trillion[30].

Neglect and abuse of the ocean and the effects of global climate change will make life worse for everyone. But historically underrepresented and underserved communities—including women—will bear a disproportionately large share of the burden. These groups are most vulnerable to food insecurity, loss of livelihoods and sea level rise. They are also the most likely to suffer from the many crimes and human rights violations that take place on the ocean, including human trafficking and smuggling, slave labour and peonage (debt slavery) systems.

A New Relationship with the Ocean Is Needed—One That Creates a Healthy Ocean and a Sustainable Ocean Economy

In contrast to a conservation philosophy of minimising destruction and an extractive approach that focuses on exploiting the ocean to create wealth, a sustainable ocean economy brings diverse stakeholders together to achieve common goals—the three Ps of effective protection, sustainable production and equitable

Figure ES.1. A Sustainable Ocean Economy Can Create a Triple Win for People, Nature and the Economy



Note: MPAs: Marine protected areas. GHG: Greenhouse gas emissions.
Source: Authors, drawing on the following sources: OECD. 2016. The Ocean Economy in 2030. Directorate for Science, Technology and Innovation Policy Note, April. https://www.oecd.org/futures/Policy-Note-Ocean-Economy.pdf; Konar, M., and H. Ding. 2020. "A Sustainable Ocean Economy for 2050: Approximating Its Benefits and Costs." Washington, DC: World Resources Institute. https://www.oceanpanel.org/Economicanalysis; Costello, C., L. Cao, S. Gelcich et al. 2019. "The Future of Food from the Sea." Washington, DC: World Resources Institute. https://www.oceanpanel.org/blue-papers/future-food-sea; Hoegh-Guldberg, O., et al. 2019. "The Ocean as a Solution to Climate Change: Five Opportunities for Action." Washington, DC: World Resources Institute. https://oceanpanel.org/sites/default/files/2019-10/HLP_Report_Ocean_Solution_Climate_Change_final.pdf.

prosperity. In this new paradigm, groups work together by adopting integrated and balanced management of the ocean in which each of the three Ps contributes to the others. Sustainable production based on regenerative practices (such as climate-ready, ecosystem-based fisheries management or seaweed farming) along with fully protected areas, for example, can help restore ocean health. The result is a triple win for nature, people and the economy and a world where prosperity is greater and more equitably distributed than it is today (Figure ES.1).

Protect effectively

Protecting the ocean doesn't mean just leaving it alone—it means managing human activity wisely, in order to preserve biodiversity and critical habitats, allow the ocean to sustainably yield greater benefits and preserve the ocean's cultural and spiritual value. In some areas, significantly scaling back or prohibiting human activities will be necessary to allow ecosystems to recover and regenerate. In most areas, sustainable practices will be needed that both allow the ocean to produce and maintain ocean health.

Far from holding back production, restoring and maintaining the ocean's health represents the best way to generate ocean-based wealth and make the most of the ocean's unique resources. This new way of thinking is also marked by a shift from incremental improvement to ecosystem-based integrated management and from a narrow focus on gross domestic product (GDP) alone to one that takes account of both the monetary and nonmonetary benefits and assets of the ocean.

A sustainable ocean economy would help protect the ocean by reducing the carbon dioxide emissions that are threatening it.

Ocean-based activities could provide one-fifth of the carbon mitigation needed to meet the Paris Agreement goals by 2050, reducing global greenhouse gas emissions by up to 4 billion tonnes of carbon dioxide equivalent in 2030 and up to 11 billion tonnes in 2050, according to research commissioned by the Ocean Panel[31]. Emission reductions of this magnitude are equivalent to the annual emissions from 2.5 billion cars or all of the world's coal-fired power plants.

Protecting coastal habitats and the ocean's biodiversity would help the ocean continue to provide the ecosystem services humanity depends on.

A restored and protected ocean would help mitigate the impact of storm and sea level rise, saving lives and livelihoods, and would reduce economic costs of damage and recovery. Healthy coral reefs, for example, reduce wave energy by up to 97 percent, potentially protecting up to 100 million coastal inhabitants from storm risks[32]. By reducing wave heights, mangroves reduce flooding of coastal areas and contribute to biodiversity. Marine protected areas (MPAs) that are fully protected from extractive and destructive activities can rebuild and safeguard biodiversity, mitigate climate change (by preventing emissions from the disturbance of sediment carbon by bottom trawling) and boost the productivity of fisheries in areas surrounding MPAs through the spillover of fish[33].

Protecting the ocean from pollution could catalyse deeper reform of contaminating, wasteful material management practices on land.

The problem of ocean pollution starts on land. Plastic—along with numerous other pollutants, including pharmaceuticals and excess nutrients—enters the ocean because systems for their proper disposal on land are inadequate. The most effective way of stopping pollutants from entering the ocean is to tackle the root causes of pollution on land. Shifting to a 'circular economy'—a system in which resources are designed to be used continually and at their highest possible value added and recovered or regenerated as efficiently as possible at the end of their service—would yield enormous benefits for the ocean economy. Agricultural regulations aimed at reducing ocean dead zones could result in farmers adopting precision agriculture practices to reduce runoff, which would also improve the health of the soil and the quality of water in rivers and streams.

Produce sustainably

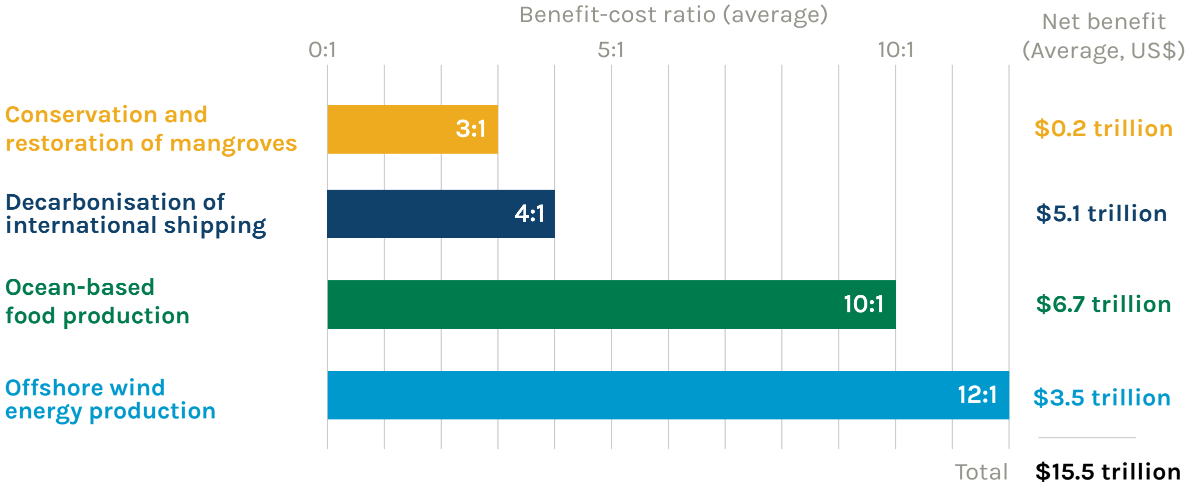
When the ocean is managed effectively, it can produce more and its production can be more sustainable. A shift to a sustainable ocean economy would increase food and energy production without putting extra pressure on marine ecosystems.

The volume of food production from the ocean could soar, helping increase food security for almost 10 billion people in 2050.

The ocean's ability to sustainably produce food is vastly under-realised. Managed better and sustainably, the ocean could produce up to six times more food than it does today—and it could do so with a low environmental footprint[34].

Most fishing today is not economically or ecologically optimised. Too many boats pursue too few fish in ways that are short-sighted and destructive. Too much seafood value is lost to poor handling. Too many non-

Figure ES.2. Sustainable Ocean-based Interventions Have Very High Benefit-cost Ratios and Could Yield Trillions of Dollars of Benefits



Note: Average benefit-cost (B-C) ratios have been rounded to the nearest integer and the net benefits value to the first decimal place. The B-C ratio for mangroves is the combined ratio for both conservation- and restoration-based interventions. The average net benefits represent the average net present value for investments and are calculated over a 30-year horizon (2020–50).

Source: Konar, M., and H. Ding. 2020. "A Sustainable Ocean Economy for 2050: Approximating Its Benefits and Costs." Washington, DC: World Resources Institute. https://www.oceanpanel.org/Economicanalysis.

target species are accidentally caught. If this approach continues, the yield in 2050 is expected to be around 16 percent lower than it is today[35]. In contrast, if all stocks currently exploited were fished at the maximum sustainable economic yield, production could increase by 20 percent over current production levels and by 40 percent over the catch forecast under a business-as-usual scenario[36].

The mariculture story is even more promising. The potential to expand finfish mariculture is significant if farms avoid adversely affecting surrounding ecosystems and use fish feed that is not made from wild caught fish. Unfed mariculture also holds great promise. Bivalves (such as oysters and mussels) and seaweed can substantially increase the production of nutritious food and feed, with little negative impact on the marine environment. In some cases, this kind of mariculture could actually enhance wild fisheries by creating artificial habitats and nursery grounds for fish.

About 35 percent of fish and seafood is currently wasted in the value chain. Reducing this wastage could boost consumption without increasing production[37].

The ocean can provide a virtually limitless supply of clean, renewable energy.

Offshore wind turbines could generate 23 times more power than the present total global electricity consumption[38]. Other potential sources of ocean-based renewable energy—producing energy from waves and tides, salinity and temperature gradients, and floating solar photovoltaic panels, for example—are still in their infancy but hold promise.

Investments in the ocean are highly cost-effective.

Investment of $2.8 trillion today in four sustainable ocean-based solutions—conservation and restoration of mangroves, decarbonisation of international shipping, sustainable ocean-based food production and offshore wind production—would yield net benefits of $15.5 trillion by 2050[39]. All four interventions have high benefit-cost ratios (Figure ES.2).

Prosper equitably

Left unmanaged, a growing ocean economy could exacerbate economic inequality, as strong, elite incumbents capture the benefits of the ocean while vulnerable and marginalised groups become increasingly exposed to economic, social and cultural impacts, including displacement.

Inequality is a structural feature of the current ocean economy. Women, for example, represent just 2 percent of the world's formal maritime workers[40]. Poor, vulnerable and marginal communities are bearing—and will continue to bear—the worst effects of global climate change. A sustainable ocean economy would not only create greater wealth, it would also create a world in which resources are distributed more evenly and where all ocean users have an opportunity to have a voice in critical decisions.

A sustainable ocean economy would create new and better jobs.

By some estimates, it could create 12 million net jobs[41]. Some sectors, particularly fisheries, will need to shed jobs. Support schemes will be needed to manage the transition to lower capacity and more sustainable management of fish stocks.

Other sectors will grow significantly. Thousands of new jobs will be created in engineering, information technology, applied science and related areas. The number of jobs in mariculture and offshore wind is projected to soar, and the increase in seaborne cargo volume and the expansion of ports are expected to create millions of jobs. Decarbonising shipping will be critical to ensure that this expansion does not come at the cost of the ocean's health.

The new agenda would empower local fishers.

The yields of millions of artisanal fishers are far lower than they used to be, partly because of the open-access model of much of the ocean, which has resulted in overfishing. A better-managed approach would benefit many of them.

Empowering fishers by granting them access rights in exchange for sustainably managing their resource is one of the levers of the sustainable ocean economy. Doing so has already proven effective. In the territorial use rights fisheries (TURFs) that Chile created, for example, catches by artisanal fisheries have surpassed industrial catches, and the biomass and size of the target species has risen[42]. Similar approaches have met with great success in many fisheries, recovering depleted fisheries and enabling them to thrive[43].

International collaboration and transparent supply chains could significantly reduce maritime crime.

IUU fishing is estimated to account for 20 percent of the world's catch (up to 50 percent in some areas)[44]. Illegal fishing is also often an indicator of other types of crime at sea, including labour and human rights violations, money laundering and tax fraud.

Acting sustainably would help preserve the cultural importance of the ocean.

The ocean is more than just a source of economic wealth. It also has spiritual, cultural and recreational value to billions of people[45]. For many Indigenous peoples, it is a key aspect of their culture. Well-designed marine protected areas and other effective area-based conservation measures can help preserve pristine ocean areas and culturally important ocean areas (such as sacred sites, historic wrecks and sea graves).

The ocean should be a key part of the massive global economic recovery from the COVID-19 contraction

COVID-19 has temporarily halted economic activity in the ocean economy, causing significant income and revenue losses to tourism, fisheries and mariculture, and shipping; adversely affecting the ocean's health; and exacerbating gender and income inequalities. The disruptions have led to cascading and interrelated impacts. The decline in tourism, for example, forced some communities to turn back to unsustainable fishing as a food source, putting pressure on coastal fisheries and reefs.

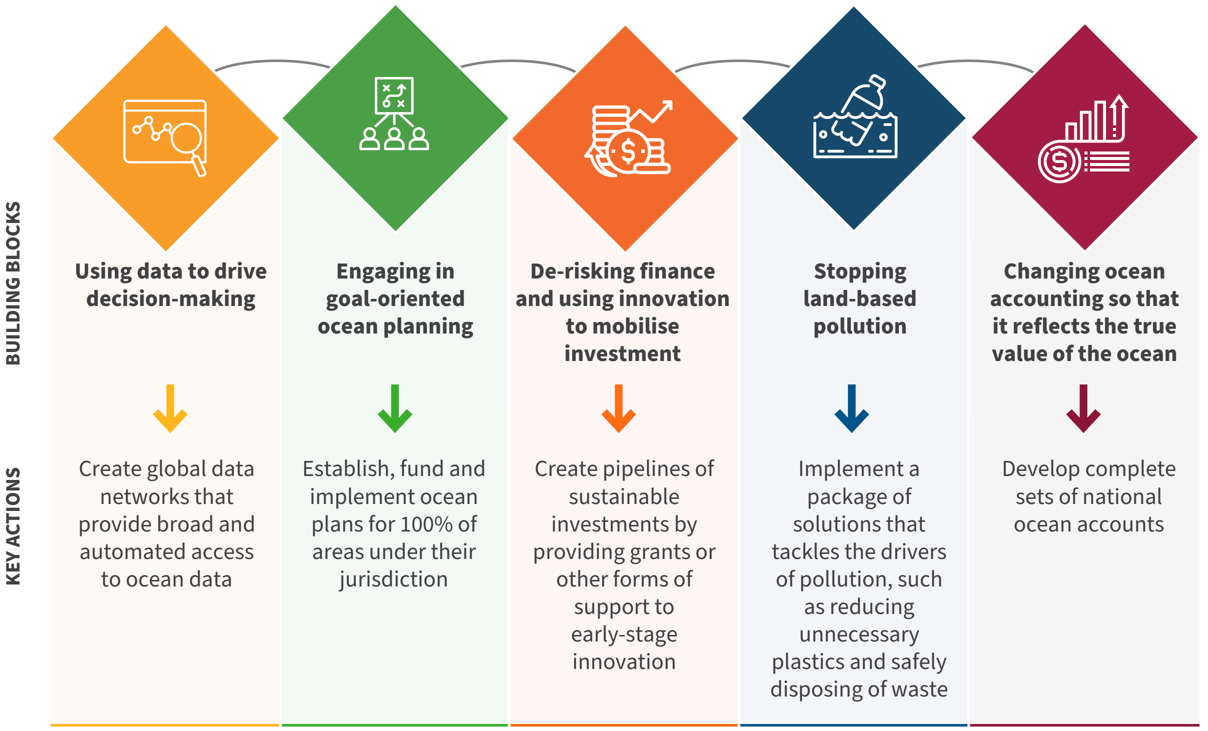
A key objective of the massive recovery from the COVID contraction will be to restore economic activity without simply restoring old patterns of environmental degradation, instead creating a more sustainable and more resilient future. The ocean economy can play a critical role in this process. Investment in five areas—coastal and marine ecosystem restoration and protection, sewage and waste infrastructure, sustainable unfed mariculture, zero-emission marine transport and sustainable ocean-based renewable energy—could create jobs and spur economic growth in the immediate term[46].

Investments made over the coming months and years will have long-term effects on the nature of the world's economies and their resilience to shocks. Efforts must be made now to avoid locking in high-emitting, high-polluting and inequitable pathways and locking out regenerative and sustainable futures. The opportunity to reset and rebuild a stronger, more equitable, more resilient and sustainable ocean economy should not be missed.

The Challenges Are Great, but a Pragmatic Action Agenda Offers Solutions to Meet Them

A world in which effective protection, sustainable production and equitable prosperity go hand in hand is possible. But it will not happen if business as usual continues. Without action, ocean planning will continue to be largely ad hoc, fish stocks will continue to decline and land-based polluters will continue to use the ocean as a liquid dump.

Figure ES.3. Five Building Blocks Are Key to Creating a Sustainable Ocean Economy



Source: Authors.

Political and business decisions made now and over the next 30 years could change this trajectory. With action, more systematic, ecosystem-based, inclusive spatial planning would become the norm. Access rights for specific ocean resources would be clarified, eliminating conflicts over resources and ensuring that the wealth of the ocean is equitably distributed. Wild fish stocks would recover, and significant increases in sustainable mariculture would provide nutritious food for billions of people, ensuring food security. Polluters would be subject to legal and political actions that would limit their ability to pollute the ocean.

Maintaining a healthy ocean will require action on many fronts and across multiple sectors

Delivering effective protection, sustainable production and equitable prosperity is an inspiring and feasible vision that is backed by science. The transition to a sustainable ocean economy will require a realignment of incentives, in-depth reforms of how the ocean is used and managed, and the empowerment of ocean users who are vested in enhancing ocean health.

Governments and businesses can take hundreds of sector-specific actions to improve ocean sectors, from supporting ocean-based renewable energy to create jobs in the wake of the COVID-19 contraction to supporting ecotourism and banning pollutants. These efforts are important, but without getting the fundamentals right, it will not be possible to transform the entire ocean system towards the desired sustainable model. Five building blocks can set the foundation for a sustainable ocean economy (Figure ES.3). These building blocks put the conditions in place for wider change across various ocean sectors. With these foundations in place, sector-specific reforms, innovations and research can be implemented and accelerated.

Using data to drive decision-making

Technologies for sensing, simulating, forecasting, tracking, managing and sharing data on open-access platforms have the potential to transform the ocean economy. New technologies can be used to register ocean-related rights and contracts, facilitating rights-based management[47]. Product tracking throughout the supply chain can help brands embrace sustainable practices and small producers connect to global supply chains. Applications can help manage fishing areas and quotas, adjust shipping traffic and avoid endangered species bycatch. In the near future, every ship's journey—and the nature of its business at sea—will be public information. Lawbreakers such as illegal fishers, polluters, smugglers and labour law violators will literally be on the public radar and subject to arrest.

Some of these technologies are already being used on a limited scale. The POSEIDON model, for example, simulates the feedback loop between fishery policies, fishing fleets and ocean ecosystems, allowing policy alternatives to be compared[48].

But barriers stand in the way of fully harnessing the power of science and data. Collecting data is very expensive, with most sensors custom-built for narrow and specific scientific missions[49]. Technological innovation in the ocean has therefore been driven largely by governments and large-scale commercial interests.

Data are fragmented into national, corporate and academic domains. Access to data is limited, and data can be difficult to use. Tools designed for marine managers, for example, are often so technical that only programmers are able to use them. Poorer countries and ocean users have little or no access to data that could help them adopt sustainable practices.

KEY ACTIONS: Overcoming these and other barriers requires the creation of global data networks that provide broad and automated access to ocean data. Governments can lead the way by mandating these standards and helping create data networks that aggregate decentralised data into a common, searchable database. They can require that data sharing be a non-negotiable condition of access to public resources—whether the resources are fish stocks and mineral deposits or funds for coastal management or for research. To achieve or improve accountability, governments can prioritise technology-forcing regulations governing the real-time monitoring of fishing, seafood imports, shipping emissions, mining, coastal development and pollution.

Engaging in goal-oriented ocean planning

The sector-by-sector assortment of regulations for some ocean activities, coupled with an open-access model for others has contributed significantly to today's decline in ocean health and cannot continue. The shortcomings of the system are evident. Open-access fisheries almost always fail[50]. Uncoordinated ocean development creates operational inefficiencies, conflicts over use and environmental degradation that undermines future productivity. Unrestricted industrial, nutrient and carbon-related pollution is changing the ocean's chemistry and affecting its biology and economic potential.

Given the interconnectedness of the ocean's sectors, it does not make sense to manage them separately. Ecosystem-based management, science-based marine spatial planning and integrated ocean management are tools that can be used to facilitate more systematic and equitable management of the ocean's resources and services. Some locales are already using ecosystem-based management tools that are science-based and grounded in broad stakeholder engagement and focus on achieving a healthy and resilient ocean ecosystem—with excellent results. Xiamen, China, for example, has seen a 40 percent improvement in socioeconomic benefits from its marine sectors since it adopted integrated ocean management in 1994[51].

A variety of barriers has held back the widespread uptake of goal-oriented planning. Standards and practices for planning, accountability, transparency and legal rights or protections in the ocean remain a century or more behind their land-based equivalents—partly because businesses fear that integrated planning is a way for conservationists to pursue an antibusiness agenda. Top-down planning processes have failed to engage all users, resulting in inefficient processes and a lack of buy-in and implementation.

To be successful, ocean plans must find a balance between the requirements of different ocean users, between the needs of the ocean and the needs of the coast and its people. Growing evidence from countries in which integrated ocean planning has been used shows how the agendas of ecosystem health, food and energy security, local prosperity and coastal protection can reinforce one another. Scientific and local knowledge are key to understanding co-benefits and navigating the trade-offs.

Ocean planning needs to provide inclusive, equitable access by and recognition of local communities. Local fishers must have access to traditional fishing grounds, cultural sites must be protected and viewsheds must be preserved. Representatives of all types of ocean users must be involved in planning. Resource owners, lessees and access holders must be given secure titling and reliable and effective legal recourse against polluters, trespassers and other violators.

KEY ACTIONS: To ensure that goal-orientated planning becomes a reality, countries should establish, fund and implement ocean plans for 100 percent of the areas under their jurisdiction, using a process that is science-based, inclusive, participatory and adapted to the local context. Doing so is crucial to balancing protection and production and ensuring equitable access and rights for local users.

De-risking finance and using innovation to mobilise investment

Current investment in sustainable ocean industries, biodiversity and conservation is grossly inadequate. It needs to quadruple to restore and sustainably maintain ocean health[52].

Investment is limited for a variety of reasons. The fact that externalities such as the effects of ocean sector activities on global climate change, pollution and human rights are not reflected in the prices producers receive means that ecologically unsustainable businesses can thrive. Harmful subsidies—typically supporting the expansion of large-scale industrial fishing fleets and fossil-fuel extraction —distort the ocean economy.

In some cases, investing in sustainability is a long-term proposition. Rebuilding fish stocks and fishing sustainably can make business sense in the long run, for example, but can be costly in the short to medium run. As a result, opportunities are missed. Governments could help solve the problem by providing resources to mitigate transition challenges—by, for example, repurposing subsidies and implementing fishery reforms that prevent overfishing and help ensure a strong return on investment.

KEY ACTIONS: Countries that establish sustainable ocean development as a national priority can hope to attract investment from sovereign wealth funds and development finance institutions. Through their own and other public or philanthropic funding sources, private investment capital can be de-risked, catalysing private investment in novel industries and business models like sustainable fisheries (reforms), or MPAs financed by tourism fees. This bending of public and private capital can be especially catalytic in increasing investments in developing nations. Governments can also help stimulate the pipeline of sustainable ventures and projects by providing grants or other forms of support to early-stage innovation, as Norway has done to support next-generation offshore aquaculture and the European Union has done to support offshore wind generation. In the offshore energy sector, governments could support renewable energy by providing low-cost infrastructure, setting feed-in tariffs and providing subsidies for sustainable activities. They could also reduce risk—by ensuring regulatory certainty, providing insurance and providing offtake/demand guarantees, particularly for capital-intensive offshore investments such as wind energy and large-scale mariculture.

Stopping land-based pollution

Virtually every pollutant present on land is also present in the ocean, with compounding and significant deleterious impacts on ecosystem health. Plastics, nutrients (primarily nitrogen and phosphorus), pesticides and parasiticides, antibiotics and other pharmaceuticals, industrial chemicals, oil and gas, heavy metals, toxins, medical waste, e-waste and other types of debris are diverted to the ocean with very few financial consequences for the polluter.

These materials end up in the ocean because waste management and sewerage infrastructure in many countries, especially Asia and Africa, are inadequate. Waste collection is largely unprofitable because few consumer products are recyclable.

Addressing the ocean pollution challenge has been complicated by the difficulties of attribution (many pollutants come from more than one source) and the overwhelming asymmetry of the situation: When heavily protected land-based private interests clash with the interest of a weakly defended common pool resource like the ocean, the ocean loses.

A growing number of governments and industries are taking action. Measures such as banning plastic bags are welcome, but their effect will be insufficient. Current commitments on plastics, for example, are likely to reduce annual plastic leakage into the ocean by only 7 percent by 2040[53].

KEY ACTIONS: To stop the leakage of plastics into the ocean, a diverse and more ambitious set of solutions is needed that includes reducing unnecessary plastics, recycling materials and safely disposing of waste. Recycled materials must become cheaper than virgin plastic. Companies must be held accountable for how much plastic they use and whether they use recycled content, recyclable product designs and plastic substitutes. Massive investment must be made in waste collection and recycling technology and infrastructure, particularly in developing countries, where such infrastructure is weak. Tackling the underlying cause could also help reduce other pollutants. Adopting precision agriculture on land could help reduce nutrient runoff into the ocean, for example.

Changing ocean accounting so that it reflects the true value of the ocean

Traditional measures of the economy, such as GDP, ignore externalities, such as the effect of production on pollution or global climate change. They also fail to place a value on natural resources and ignore the way benefits are distributed.

Measuring only the GDP generated by ocean-based sectors does not capture the true value of the ocean—and can reward unsustainable practices. The ocean's broader value must be fully accounted for and used in decision-making, based on a holistic set of metrics that includes measurements of infrastructure assets, such as ports; natural assets, such as fish populations and coral reefs; and indicators of benefits to people, such as measures of income and well-being.

KEY ACTIONS: To measure the value of the ocean more accurately, national statistical offices, in partnership with other agencies, need to develop complete sets of national ocean accounts. Interactive dashboards should be created to allow users to explore the data by aggregating and disaggregating sectors and groups of people.

Having these five building blocks in place will enable change in key ocean economy sectors such as sustainable food from the ocean, renewable energy from the ocean and sustainable tourism. These sectors will also need targeted and sector-specific actions in terms of policies, technology and finance innovation, and scientific research, but having these building blocks in place will set governments and other stakeholders on the right path and lay the groundwork for the achievement of a prosperous and sustainable ocean economy.

This new way of thinking about and managing the ocean is gaining traction

The ocean is moving up the policy agenda. Coastal countries, especially small island states, are advocating for socially equitable and environmentally sustainable growth. Civil society is increasingly recognising the decline in the ocean and favouring government action to protect the ocean.

The action agenda is ambitious but entirely feasible. Progress in building the foundations for change is already evident:

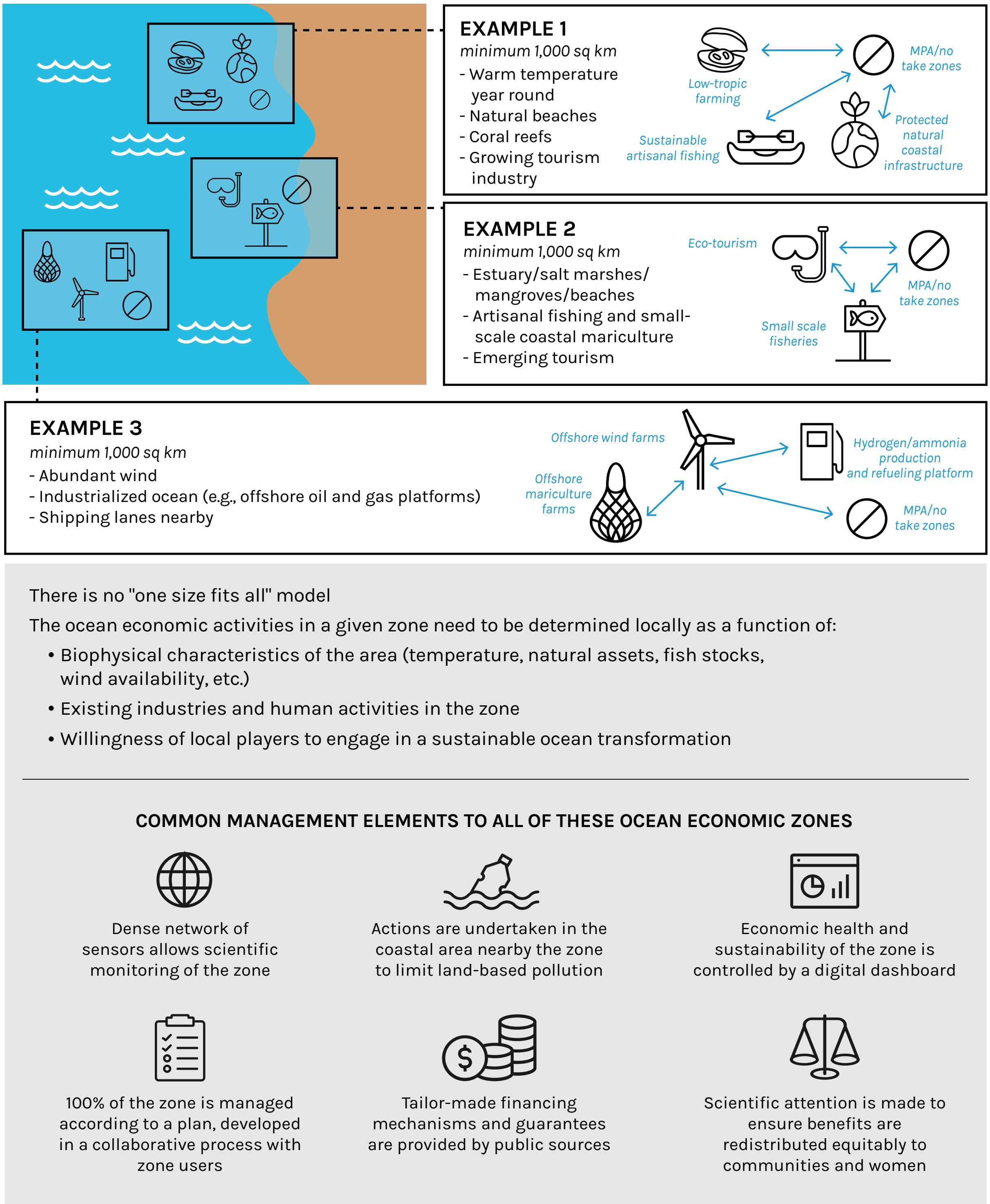
- The data revolution has begun. Sensors and satellites are increasingly being deployed to monitor the ocean. Data on invasive species in bilge water and nutrients in river deltas, for example, provide actionable information in near real time—the holy grail of adaptive management. Sound fishery management digital tools, including vessel tracking, fishery simulation, and registry and enforcement systems, are widely available.
- Several regions have replaced siloed management practices with more integrated marine spatial planning. For example, the Baltic Sea states have coordinated across borders and sectors to implement a science-based planning strategy and have been rewarded with the return of predators and birds as well as restored fish stocks[54].
- Sustainable ocean investments are on the rise. In a recent survey, 72 percent of investors classified the sustainable ocean economy as investable[55]. Thousands of sustainable ocean ventures are emerging across all continents.
- Together, the United States, Europe and Asia adopted 95 policies and pieces of legislation limiting plastic packaging between 2010 and 2019.
- A growing number of countries are adopting more holistic accounting techniques. China, for example, is using gross ecosystem product (GEP) to steer its transition towards inclusive, green growth[56].

Similar trends can be observed at the ocean sector level. Backed by industry, support is growing for green shipping, the development of new technologies and practices that reduce the impact of mariculture on ecosystems, and community-led programs restoring fish stocks, to name just a few emerging changes. Inspiring success stories, such as the reform of fisheries in the United States, demonstrate that sound ocean management can simultaneously restore fish stocks and benefit fishers and coastal communities[57]. To achieve a sustainable ocean economy, change needs to happen faster and at a bigger scale than is currently happening. Actions at the local and national level can help accelerate change.

Targeted actions can help accelerate progress

The huge scale of the challenge and the high stakes involved mean that acting quickly and effectively is crucial. Delivering immediate gains can help demonstrate the long-term benefits of pursuing a sustainable ocean economy, spurring stakeholders to take action. Creating sustainable ocean economic zones and forming national task forces are concrete actions than can move the agenda forward right away.

Figure ES.4. Sustainable Ocean Economic Zones Can Be Test Beds for Experimentation and Innovation



Source: Authors.

Sustainable ocean economic zones can illustrate the benefits of a sustainable ocean economy at a small scale.

Special economic zones (SEZs) are areas within a country that the government sets aside to attract direct investment in particular economic activities. These zones typically offer low rents, taxes, utilities and infrastructure costs; relief from bureaucratic procedures; and loan guarantees to market-rate investors. They range in size from small neighbourhood zones to entire cities.

Taking inspiration from the success of the SEZ concept in a country's exclusive economic zone (the ocean zone

Figure ES.5. A Healthy Ocean Is Critical to Meeting the Sustainable Development Goals

NO POVERTY

Sustainable ocean growth means sustained growth, which is able to lift and keep people out of poverty

ZERO HUNGER

Farming and fishing sustainably has the potential to produce far more protein than a 2050 population requires

GOOD HEALTH AND WELL-BEING

Apart from being able to provide more nutritious food, a healthy ocean is the recharging point for billions of people

QUALITY EDUCATION

Lifting marginalised coastal communities out of poverty increases their children's chances for a good education

GENDER EQUALITY

Increasing gender equality in the ocean economy would empower millions of women

CLEAN WATER AND SANITATION

Desalination of ocean water provides drinking water to millions of people. Additionally, improving sanitation can increase coastal water quality

AFFORDABLE AND CLEAN ENERGY

Expanding the ocean's almost unlimited renewable energy potential is predicted to contribute 10% of the global electricity production increase by 2050

DECENT WORK AND ECONOMIC GROWTH

Growing the ocean economy sustainably is projected to more than double the current ocean economy

INDUSTRY, INNOVATION AND INFRASTRUCTURE

Constructing low carbon ports and renewable ocean energy will stimulate innovation and create vital infrastructure

REDUCED INEQUALITIES

Granting well-defined ocean access rights and sustainable resource use ensures long-term prosperity of marginalised groups

SUSTAINABLE CITIES AND COMMUNITIES

Constructing blue-green storm protection infrastructure will make cities more sustainable

RESPONSIBLE CONSUMPTION AND PRODUCTION

Solving ocean plastic pollution drives us to build a more circular economy on land

CLIMATE ACTION

Growing ocean industries sustainably can contribute up to one-fifth of greenhouse gas savings towards achieving a 1.5^{o}C future

LIFE ON LAND

Reducing ocean dead zones catalyses land-based reforms towards regenerative precision agriculture

PEACE, JUSTICE & STRONG INSTITUTIONS

In a sustainable ocean economy, a nation's sovereignty over its exclusive economic zone and resources is achieved

PARTNERSHIPS FOR THE GOALS

The ocean is a platform for collaboration and strengthens the global partnership for sustainable development

Note: Regarding SDG 6 (clean water and sanitation), the link to the ocean can be made through desalination plants. Regarding SDG 17 (partnerships for the goals), the ocean provides excellent platforms for collaboration. Peaceful ocean science collaboration, for example, has been important for diplomatic relations (e.g. U.S.-Soviet Gulf Stream experiments in the 1960s).

Source: Authors.

over which a coastal state has special rights with respect to marine resources) could be a powerful catalyst for accelerating a sustainable ocean economy. Sustainable ocean economic zones (SOEZs) could provide a test bed for systemic experimentation and innovation, where incentives could be tested, results monitored and adapted to, and risks managed. In the process of designing and implementing these zones, the classic hurdles to ocean management—free access, lack of planning, conflicts over use and externalities—can be addressed in the context of real business, rather than as abstract policy.

SOEZs are a way for countries to support and evaluate the sustainable ocean economy model at a scale they are comfortable with. Biological conditions, existing industries and stakeholders, and local needs determine which activities take place in an SOEZ (Figure ES.4). One locale might use a SOEZ to attract and test high-technology models combining energy generation, shipping and large-scale mariculture. Another might combine carbon-financed restoration, coastal protection, tourism and fishery enhancement.

Whatever activities take place within the zone, all SOEZs share several common elements. The entire zone is managed according to a plan, a dense networks of sensors allows scientific monitoring of the zone and efforts are made to ensure that benefits are redistributed equitably to communities and women.

National ocean task forces can accelerate the shift towards a sustainable ocean economy.

Establishment of a sustainable ocean task force at the (ocean) ministerial or head of state level with a mandate to adapt the sustainable ocean agenda to the national context could accelerate change. Such a task force could perform several important functions:

- Conduct a comprehensive marine resource mapping of 100 percent of the country's exclusive economic zone.
- Support and facilitate an inclusive, participatory process to develop a plan that ensures a streamlined and efficient regulatory process, avoids conflicts over spatial use and protects and sustains key oceanic systems.
- Bring together relevant ministries and the head of state on the steps required to accelerate the transition towards a sustainable ocean economy, including financial guarantees and risk-reduction measures, policy and regulations, and international coordination.
- In coordination with relevant organisations, academic institutions and civil society groups, lead special initiatives, such as the design of networks of marine protected areas and SOEZs and efforts to control land-based pollutants.

National task forces can be a way to highlight the relevance of the ocean economy to national priorities like food security, international trade and tourism.

The Ocean Is Not Too Big to Fail, and It Is Not Too Big to Fix, But It Is Too Big and Too Central to the Planet's Future to Ignore

Effective ocean protection, sustainable ocean production and equitable human prosperity are inseparable and compatible. When integrated into a sustainable ocean economy, they can change the current downward trajectory of ocean health, producing positive outcomes for people and nature. Setting the foundations within which the three Ps can be achieved and transforming key ocean sectors will not be easy, but it can be done. Doing so would vastly increase the resilience of the global economy and improve the lives of some of the world's poorest and most vulnerable people. Indeed, creating a sustainable ocean economy would help the world meet all of the Sustainable Development Goals (SDGs), not just SDG 14 (on life below water) (Figure ES.5).

Current practices, laws and cultural norms help support the open-access model that characterises much of the ocean. All of them can change. History shows that even very complex systems can shift onto new trajectories, sometimes very quickly. The energy transition in Germany, the banning of smoking in bars and restaurants in much of the world, and the adoption of the Montreal Protocol on Substances that deplete the ozone layer are all examples of changes that required major shifts in attitudes and laws that occurred within the space of a few years.

This kind of change can and must take place among stakeholders in the ocean economy. Spearheaded by a new cohort of ocean interests deeply vested in ocean health—sustainable fishers and mariculturists, coastal communities, renewable energy generators, ecotourism operators, scientists, environmentalists, social and civil society organisations—pollution and over-exploitation can be counteracted.

The journey towards a sustainable future has already begun, with pioneers leading the way. New sustainable technologies are attracting investors, and businesses and governments are waking up to the opportunities of a sustainable ocean economy in building a new future after COVID-19. They are also increasingly recognising the risks and cost of inaction. Inspiring efforts from around the world provide a glimpse of what can be achieved globally if stakeholders act now.

PROLOGUE

Five Sustainable Ocean Economy Stories

Figure P.1. Five Sustainable Ocean Economy Stories

Design inspired by Athelstan Spilhaus, Atlas of the World, Geophysical Boundaries, Map XIIIA: "World Ocean Map in a square", conformal, poles in South America and China, 1979.
Source: Authors.

What does a sustainable ocean economy look like? Before exploring the rationale, benefits and practicalities of the concept, let's travel to five inspiring places (Figure P.1). The first destination is Gazi-Kwale County, Kenya, where a community-based organisation sells blue carbon credits from rebuilding its mangrove forest. The second stop is the Philippines, where a comprehensive approach used with 400 fishing communities helps meet the triple objective of food security, ocean protection and community prosperity. Then on to Europe, where the Medes Islands Marine Reserve in Catalonia, Spain, regenerates ocean biomass, supporting thriving ecotourism and, through spillover effects, sustainable fisheries. Across the Atlantic, on the U.S. East Coast, GreenWave works with fishers and coastal communities to launch regenerative ocean farms which combine seaweed and shellfish production. The final stop is the North Sea, where the Zero Emission Energy Distribution at Sea (ZEEDS) initiative aims to create a revolutionary zero-carbon fuelling system for ships, enabled by offshore wind production. This is a voyage of discoveries, and at some stops the results are not yet proved or fully backed by scientific assessments. But they are ideas, ones that illustrate a range of possibilities happening right now; they demonstrate inspiring innovations with the promise of a sustainable ocean economy. Figure P.1 (and the report cover) maps this voyage on a representation of Earth inspired by the work of South African oceanographer Athelstan Spilhaus. This projection emphasises that there is one interconnected ocean.

Stop 1. Mikoko Pamoja, Kenya

Mikoko Pamoja, meaning 'mangroves together' in Kiswahili, perfectly describes the community-based blue carbon credit project in Kwale County on Kenya's South Coast. The first effort of its kind, Mikoko Pamoja is improving the livelihood of the local community, regenerating the local mangrove forest and helping fight climate change (Figure P.2).

The reduction of local mangroves threatened the livelihood of fishers and destabilised coastlines. Mikoko Pamoja was set up to reverse this trend and find alternatives to mangroves that could provide the community with fuel and building materials while also generating income.

In 2013, a community-based organisation was formed, which was granted co-management rights for the 117-hectare coastal area from the Kenyan government[58]. A few hectares of *Casurina* woodlots were planted to provide an alternative source of fuel- and building wood for the community[59]. On 114 hectares, mangroves were replanted and a carbon credit trading scheme, now accredited by Plan Vivo (an international body regulating carbon credits), was set up[60].

Figure P.2. Mikoko Pamoja at Work

Note: (top left) Gazi Bay in Kwale County, (bottom left) GRID-Arendal & the Mikoko Pamoja committee members, (top right) Community water project founded by Mikoko Pamoja, (bottom right): close up of a mangrove.
Source: Rob Barnes, UNEP/ GRID-Arendal, https://www.grida.no/resources/11125.

The trading scheme is now up and running—Plan Vivo sells 2,500 credits per year, with 1 credit being equivalent to 1 metric ton (tonne) of carbon dioxide (CO_2) per year. These 2,500 tonnes are derived from a mix of avoided deforestation and the planting of new mangroves.

On average, the carbon sales generate about $12,500 per year. Thirty-five percent of the revenue is used for the project costs, while 65 percent is reinvested in the community[61]. In the past it has funded initiatives such as the establishment of a water system for the whole village, a local soccer tournament and textbooks for the local primary school[62].

In addition to the credit sales, the community benefits from the restored mangroves through increases in fish catches, beekeeping and ecotourism from the 'Gazi Bay Boardwalk', all of which contribute to more sustainable livelihoods[63].

Despite facing challenges such as fluctuations in carbon credit prices, the project has largely been a success and has received strong support from the Kenyan government. There has been strong scientific support with partners through the Kenya Marine and Fisheries Research Institute as well as support from the Kenya Forest Services on aspects of forest governance[64]. Mikoko Pamoja won the 'Equator Initiative Prize' and is now the model for future projects, including for 'Vanga', which covers an area about four times that of Mikoko Pamoja[65]. Mangroves are considered to be a natural climate solution because of their ability to help reduce carbon emissions, and currently there are efforts to include mangroves as part of Kenya's nationally determined contributions (NDCs). This work has also enhanced the visibility of the ocean space in Kenya and contributed to the value of safeguarding coastal ecosystems.

Stop 2. Community-Based Managed Access Network in the Philippines

Fishery reform in the developing world is not just about the fish. It is also about people, coastal communities and fishing as a livelihood, a job and a way of life[66]. Small-scale fisheries are a main source of food, provide millions of jobs and underpin cultures, particularly for the coastal poor.

Rare, an international non-governmental organisation (NGO) that applies behavioural insights to the cause of artisanal fishery recovery in developing countries, the Environmental Defense Fund, and the Sustainable Fisheries Group (SFG) at the University of California, Santa Barbara, launched the Fish Forever program in multiple countries to build a social movement for the better management of coastal fisheries. Rare and SFG took the lead in the Philippines.

Better management starts with managed access areas that give fishing communities clear, exclusive rights to fish in certain areas, which are often aligned with traditional community use rights. The communities' exclusive access is tied to their commitment to use fully protected marine protected areas (MPAs) that are designed to replenish and sustain fish populations and protect habitats and biodiversity.

In communities that have organised themselves to manage 'their' fishing areas and protected zones, management typically becomes more sophisticated. For example, boats and fishers are registered, catch is recorded, regulations are respected and fishers participate in management (Figure P.3). In the absence of outsiders skimming off the rewards of good stewardship, a virtuous circle tends to evolve, where results drive good behaviour and vice versa. Households in these communities have been shown to become more resilient in terms of food and financial security, and communities can work together to develop access to previously elusive capital and markets.

This social movement naturally kick-starts a political movement. National governments and international bodies begin to recognise the central role of coastal fisheries to the health, cultural coherence, resilience and wealth of coastal communities, and they start to promote the sector with better policies and improved access to financial resources.

The Philippines have demonstrated these dynamics at work. The 'Fish Forever' program is active in more than 400 communities in the country, clustered in 47 sites. Early results from 20 sites showed that fish biomass inside and outside the reserve was either maintained or increased across all sites. At sites where Rare had been working for seven years, the increases were as high as 390 percent inside the fully protected MPAs and 111 percent outside MPAs. There were also statistically significant increases in 80 percent of social metrics, including improved attitudes towards fully protected MPAs, participation in management and the sense of social equity. To build financial resilience in fishing communities, fisher households also organised themselves into 'savings clubs'. These enabled more than 1,500 members to save close to US$2 million in two and a half years.

The success at the local level is now reflected in a national policy agenda that supports artisanal fisheries. One example is the inclusion of managed access areas in the Philippine Development Plan, the country's central economic and development planning document. Most recently, working with Rare, 300 mayors also passed

Figure P.3. Artisanal Fishers Planning Their Community Fishery in the Philippines

Source: Rare.

major resolutions to support artisanal fishers and the issues they face regarding climate change, preferential rights and sustainable financing[67].

Stop 3: Medes Islands Marine Reserve, Spain

Two hours northeast of Barcelona, seven idyllic islets can be seen from the Costa Brava. According to the official tourism website, the Medes Islands ecosystem is 'the best natural reserve in the western Mediterranean'. Scuba divers come from all over Europe to see the abundant fish—including large Mediterranean dusky groupers and other predatory fishes—relict red coral populations, octopus and hundreds of other marine species around these islands. How is this possible in a sea known to be overfished, polluted and overrun by invasive species?

It all started over 35 years ago, with the creation of a 51-hectare no-take marine reserve which banned fishing but allowed diving, navigation and moorings only on buoys (Figure P.4). Years later, an additional 460 partially protected hectares were added. They permit limited fishing, only by a few local artisanal fishing vessels. (Only seven local vessels have this exclusive access)[68].

This protection proved successful on all fronts[69], even in this relatively small area.

Figure P.4. The Medes Islands Reserve, Spain

Sources: top: Damsea/Shutterstock; bottom: funkyfrogstock/ Shutterstock.

- Fish biomass has fully recovered, and six main species have almost reached the maximum carrying capacity of the ecosystem.
- The restored biodiversity and biomass have transformed the Medes Islands into a paradise for divers and snorkelers, supporting thriving ecotourism in the area. Two hundred full-time jobs are supported and €12 million in revenue is generated, compared with €0.5 million before the creation of the reserve.
- The net present value of the reserve is up to 12 times greater than it would have been without this effective protection and management.

Stop 4: GreenWave, United States

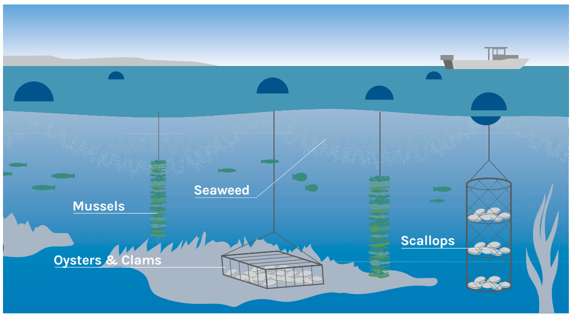
In his book *Eat Like a Fish*, Bren Smith describes his journey as lifelong fisherman turned regenerative ocean farmer. He is fascinated with species that require no feed inputs and can regenerate their surrounding ecosystem: shellfish and seaweeds. After extensive research, he began to design and build an integrated, multitrophic mariculture farm, or as Bren would call it, a regenerative ocean farm[70] (Figure P.5).

On a visit to Bren's farm, at first you will see nothing but a few buoys. Underwater, it's a different story: kelp and mussels grow on horizontal lines of ropes connecting anchored scaffolding, scallops hang in lantern nets, while oysters and clams litter seafloor cages.

According to Bren's NGO, GreenWave, regenerative ocean farms can produce up to 150,000 shellfish and 10 tons of seaweed per acre. One farm can turn a profit of up to US$90,000–$120,000 per year—all without needing or buying feed, land, freshwater or fertiliser. Considering his initial investment of $20,000, this is a profitable business for Bren and other farmers, providing year-round income as kelp is harvested in spring, clams in spring to summer, scallops and mussels in autumn and oysters year-round. The 'crop' diversification also provides security for farmers should one of the crops fail.

Getting started wasn't easy. Native shellfish (mussels, clams, oysters, scallops) seed was easily obtained from established growers nearby, but sourcing microscopic kelp seed that could eventually grow into one- to two-metre-long seaweed blades proved more complicated. While seaweed farming is a thousand-year-old industry in Asia, it is nascent in the United States. With the help of kelp scientists and local community partners, Bren and GreenWave built a kelp hatchery that could supply him and other local farmers with seed. Launched to replicate and scale Bren's farming model, GreenWave educates the next generation of ocean farmers about farming in an era

Figure P.5. GreenWave Ocean Farming Model



Note: Sketch depicting the GreenWave 3D ocean farming model (top), Bren Smith harvesting kelp (bottom).
Source: Top: Inspired by Water Brothers; Bottom: Ronald T. Gautreau Jr. for GreenWave.

defined by climate change. Through its Farmer-in-Training program, GreenWave supports aspiring regenerative ocean farmers as they navigate the complex U.S. regulatory system and teaches them the fundamentals of setting up their ocean farm. The farms are geared towards simplicity and low cost, making it possible for anyone to become a regenerative ocean farmer for '$20k, 20 acres and a boat'[71]—far less than the cost of establishing a farm on land.

GreenWave's goal is to plant 1 million acres of restorative species in the next 10 years. They hope to catalyse the growth of ocean farms across the world, providing a profitable and ecologically regenerative food production system for millions of people. These farms would be organised in GreenWave 'Reefs', with 50 small ocean farms clustered around a land-based hatchery and processing hub, surrounded by a ring of institutional buyers and entrepreneurs[72].

Stop 5. ZEEDS project, North Sea

Shipping is the most carbon efficient way (in tons per kilometre [km] travelled)[73] to move goods across the globe and accounts for 90 percent of cargo transport. Shipping today contributes about 2.2 percent of global CO_2 emissions, but these emissions could grow between 50 percent and 250 percent by 2050, mainly due to the growth in world maritime trade[74]. For instance, container shipping volumes are expected to increase by 243 percent between 2015 and 2050[75]. However, in April 2018, the International Maritime Organization (IMO) set a target of at least a 50 percent reduction in total annual greenhouse gas (GHG) emissions by 2050, compared with 2008 levels[76].

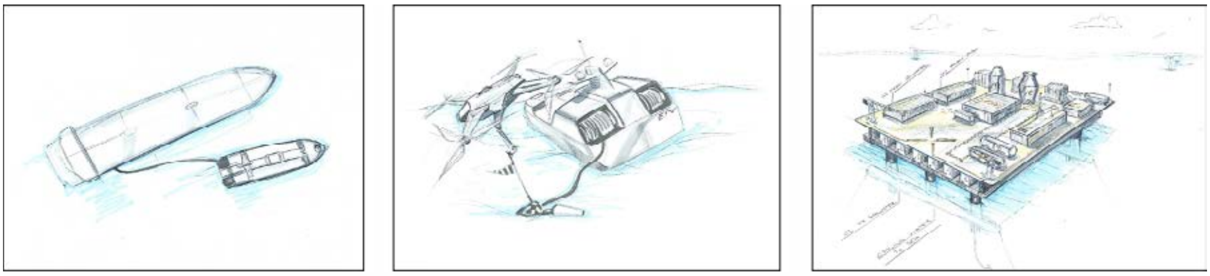
How can a traditional industry like shipping, whose assets have a lifetime of more than 30 years, achieve the IMO's target or even more ambitious decarbonisation pathways?

Let's travel to a hypothetical future in 2030. In the eastern Atlantic, a container vessel is heading towards Rotterdam. This ship is carbon-neutral, having been retrofitted to be powered by green ammonia, a combustible produced through a series of chemical reactions enabled by renewable energy. The ship is low on fuel and slows to six knots as it is met by a small autonomous refuelling ship with a fuel hose suspended in the air by a drone. After one hour, while still progressing, the now refuelled vessel accelerates on its way to Rotterdam. The fuel-provider vessel heads back to dock at a floating ammonium production platform, which is surrounded by a network of offshore wind turbines (Figure P.6).

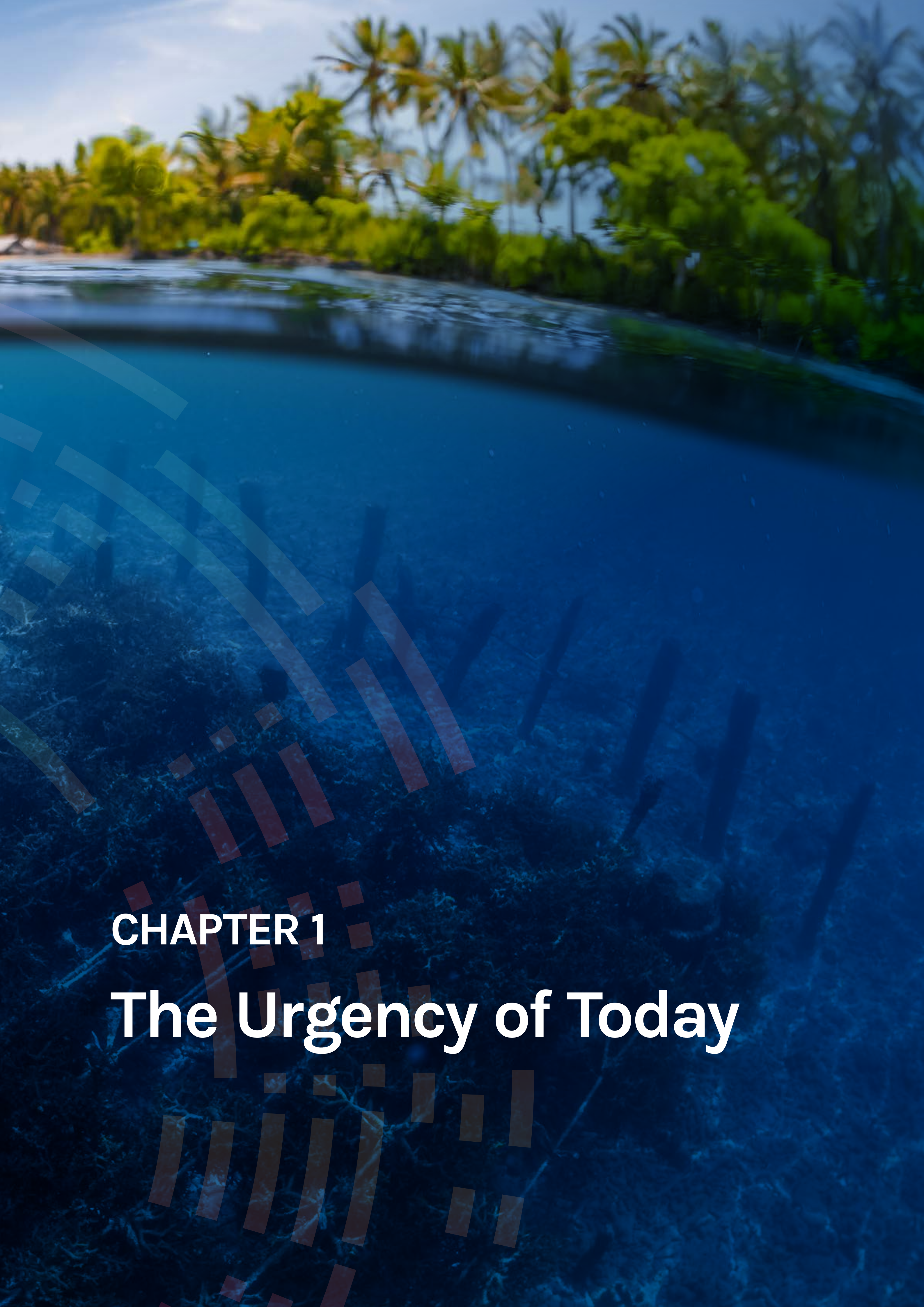
This is the vision of Zero Emission Energy Distribution at Sea (ZEEDS), a new partnership created in 2018 that gathers leading Scandinavian players in energy, offshore engineering, shipping and technology (Equinor, Wärtsilä, Aker Solutions, Kvaerner, DFDS and Grieg Star). The ZEEDS concept envisions an ecosystem of strategically located offshore clean fuel production and distribution hubs, co-located near busy shipping lanes. Wind will provide the power to create sustainable ammonia for ship-to-ship refuelling.

The good news is that this solution might be more realistic than it looks. Adapted ship engines and production technology at sea are being tested at a pilot scale, and green ammonia is looking very promising as a replacement for heavy fuel oil on long voyages.

Figure P.6. Sketches of Zero Emission Energy Distribution at Sea



From left to right: Sketch showing ship-to-ship bunkering at sea with zero carbon fuel. Sketch showing drone carrying pilot wire from energy-provider vessel. Sketch of topside of a ZEEDS platform producing and storing green ammonia.
Source: ZEEDS project.



CHAPTER 1

The Urgency of Today

Introduction

The five stories in the prologue are diverse but compelling illustrations of local actions to move towards a sustainable ocean economy. They share a common vision which recognises that the ocean will only be able to regenerate if and when the agendas of protection, production (e.g. food, energy, carbon) and human prosperity are managed holistically.

Yet these examples are exceptions to the general global downward trajectory of ocean ecosystems or their associated economic potential. Action can be inspired by their examples, but the reality is that urgent action is needed to transition towards a more sustainable ocean economy at scale.

This chapter develops three main arguments to emphasise the urgency of action:

A healthy ocean is crucial for all of humanity and for the global economy. The agenda of a sustainable ocean economy applies to the entire world, not just to traditional 'blue sectors' like fisheries or shipping. The diverse services provided by healthy ocean ecosystems make Earth liveable. Feeding 10 billion people in 2050 while remaining within a safe planetary 'operating space'[77] will be hard—and the ocean may well hold a big piece of the solution. The ocean could also play a significant role in fighting climate change, meeting up to one-fifth of the carbon mitigation challenge[78]. Finally, global concern about ocean plastic pollution could catalyse a much deeper reform of the profusion of wasteful material management practices on land (Section 1.1).

The ocean is under increasing threat. The ocean is becoming warmer, more acidic, depleted, stormier, higher, more oxygen-depleted and less predictable. Profound changes (state shifts) affecting many aspects of human life are no longer unthinkable. Neither the ocean economy as a whole, nor coastal communities, nor the social agenda of the Sustainable Development Goals (SDGs) can thrive in such a degraded environment (Section 1.2).

Solutions are emerging but urgently need to be scaled up. Despite the undeniable challenges, hints of a sustainable ocean mindset are on the rise. The pace of innovation in the ocean economy is accelerating sharply, and investors are starting to find their way to the sustainable ocean economy. A data revolution is underway—enabled by an ocean technology revolution—redefining access to knowledge. Successful, sustainable ocean-related policies are increasingly gaining traction. The voices of citizens and communities advocating for more equitable and sustainable use of planetary resources are getting louder. There is an unprecedented international momentum for a sustainable ocean economy, as seen at meetings of the G7, G20, Ocean Panel, UN Ocean Conference, Our Ocean, World Ocean Summits, UN Decade of Ocean Science and so on (Section 1.3).

1.1 A Blue Awakening: Recognising That the Ocean Is Vital to Humankind and the Global Economy

In an international 2020 survey, 94–96 percent of respondents saw 'the condition of the ocean as important to their country's economy'[79]. At the same time, there is no single broadly accepted definition of the ocean economy. The most commonly used one is the following: 'The ocean economy can be defined as the economic activities that take place in the ocean, receive outputs from the ocean, and provide goods and services to the ocean'[80].

There is considerable variation in the way this definition is interpreted—the United States includes as few as 6 industry sectors in the ocean economy, Japan as many as 33. The ocean economy's implied valuation also ranges widely. The Organisation for Economic Co-operation and Development (OECD), defining the ocean economy as 'the sum of the economic activities of ocean-based industries, together with the assets, goods and services provided by marine ecosystems'[81], initially assessed 10 ocean-based industries of the global ocean economy, conservatively estimating they represented in 2010 a total of US$1.5 trillion in gross value added [GVA])[82]; WWF calls it 'the 7th largest economy in the world', valuing ocean assets at $24 trillion[83]; and many others assert it to be practically incalculable. The ocean economy includes heavily ocean health–dependent sectors such as tourism (26 percent ocean GVA), fisheries and mariculture (2–6 percent ocean GVA), as well sectors principally managed by more exogeneous interests, such as offshore oil and gas (33 percent ocean GVA), ports (13 percent ocean GVA) and maritime equipment (11 percent ocean GVA). In terms of employment, the 10 ocean-based industries assessed by the OECD contributed some 31 million direct full-time jobs in 2010, with industrial capture fisheries accounting for the lion's share of the OECD's assessed ocean economy jobs (36 percent and plateauing), followed by tourism (23 percent and strongly increasing)[84]. If informal or artisanal jobs are included, the ocean's global employment contribution is much higher—estimates for total (formal and artisanal) fisheries employment alone run as high as 237 million full-time equivalent jobs[85].

These definitions and numbers are insightful but incomplete. To be a useful descriptor of the relationship between humans and the ocean, a broader, more systemic perspective on the ocean economy is needed, in line with the World Bank's definition of a sustainable ocean economy: 'the sustainable use of ocean resources for economic growth, improved livelihoods and jobs while preserving the health of ocean ecosystems'[86].

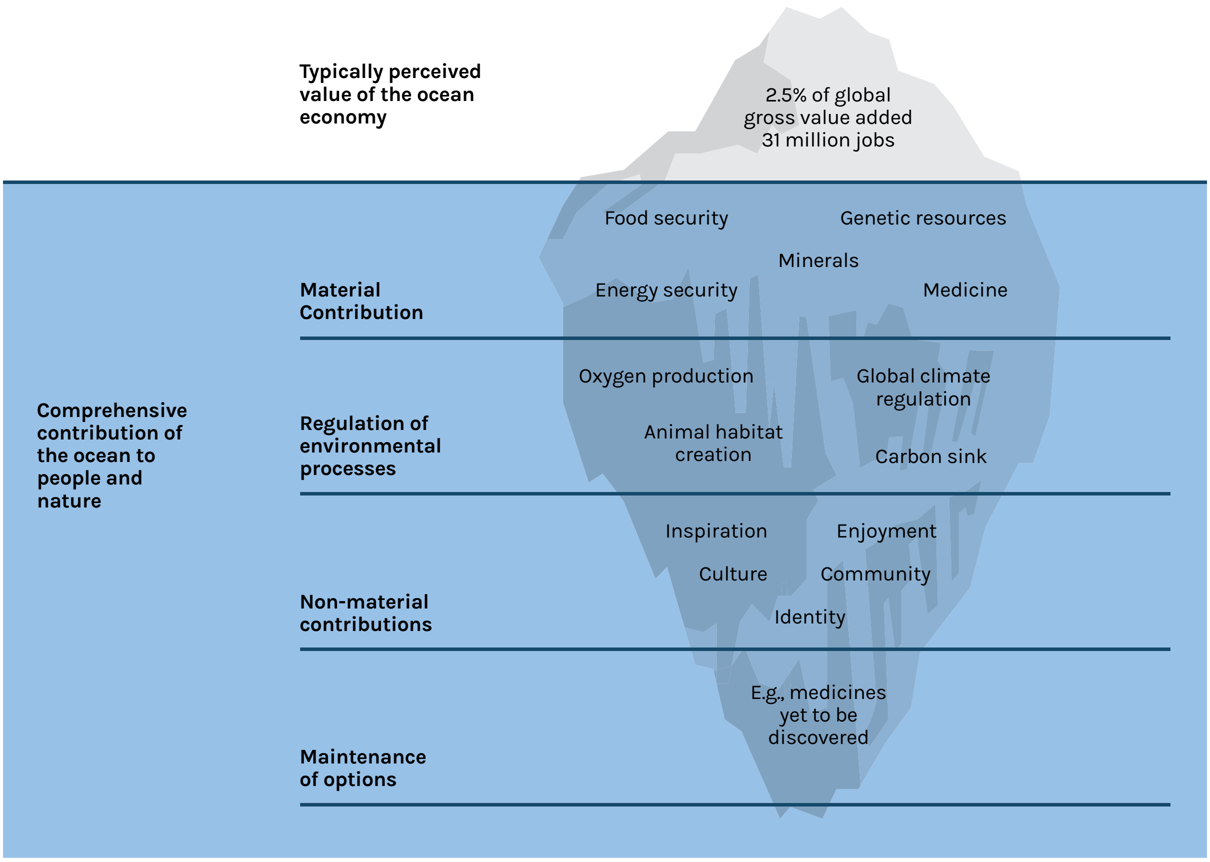
In the literature and in national or international initiatives it is common to find references to a 'blue economy', but again the definition and scope varies: sometimes 'blue' refers to the ocean, with the blue economy closer to the definition in this chapter's first paragraph; at other times 'blue' refers to sustainable (as 'green' would do for sustainable land-based activities), and the blue economy is understood as in the World Bank definition. To avoid confusion, this report will avoid the term 'blue economy' in favour of 'sustainable ocean economy', mostly guided by the World Bank definition. Yet this report also invites readers to embrace a wider paradigm that acknowledges the following:

- The importance of ocean contributions for all of humanity and nature
- The ocean's central contribution to the global agenda of food security
- The untapped opportunity the ocean provides to fighting climate change
- The catalytic role the ocean can play in accelerating a global transition towards more circular and regenerative practices in land-based economies

The ocean's contributions to humanity exceed the realm of its industrial production

The ocean absorbs more than 90 percent of the heat resulting from anthropogenic greenhouse gas emissions. It rebalances the heat differential between poles and equators. It produces 50–80 percent of Earth's oxygen[87]. Its biological adaptations remain largely unknown and, if previous experience is any indication, contain untold medical, knowledge and commercial resources. For

Figure 1.1. The Ocean's Importance to Humankind



Source: Authors, inspired by Díaz, S., J. Settele, E.S. Brondízio, H.T. Ngo, M. Guèze, J. Agard, A. Arneth et al. 2019. "Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services." Bonn, Germany: Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. doi:10.5281/zenodo.3553579; OECD. 2016. The Ocean Economy in 2030. Report. Paris: OECD Publishing. https://www.oecd.org/environment/the-oceaneconomy-in-2030-9789264251724-en.htm.

billions of coastal dwellers, the ocean is woven deeply into their cultural and spiritual lives. For all humans, it provides a sense of wonder, solace and connection to the natural world. Millions play in it every day. It provides a deep sense of place[88].

The 2005 Millennium Ecosystem Assessment report defined ecosystem services as 'benefits people obtain from ecosystems'[89]. This concept was updated and broadened to 'nature's contribution to people' in the latest report by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)[90]. The IPBES structures nature's contribution to people into three main categories (definitions below are directly inspired by IPBES's)[91]:

- **Nature's material contributions to people:** 'substances, objects or other material elements from nature that sustain people's physical existence and the infrastructure needed for the operation of a society or enterprise'. In the context of the ocean economy, these material contributions support subsistence (e.g. fish), energy (ocean fossil fuels, wind), health (e.g. pharmaceuticals derived from marine species) and construction (e.g. sand), among others. In this report it is assumed that most of these contributions are economically accounted for by conventional indicators like GVA (see Figure 1.1).
- **Nature's regulating contributions to people:** 'functional and structural aspects of organisms and ecosystems that modify the environmental conditions experienced by people, and/or sustain and/or regulate the generation of material and non-material contributions'. For the ocean and coastal ecosystems, climate regulation is a perfect example of such contributions, but the latter also include, for example, habitat creation and maintenance; regulation of hazard and extreme events; regulation of air quality; and dispersal of seeds, propagules and larvae (see Figure 1.1).
- **Nature's non-material contributions to people.** 'Nature's contribution to people's subjective or psychological quality of life, individually and collectively'. These contributions include learning and inspiration from the ocean, physical and psychological experiences, and supporting identities (see Figure 1.1).
- The IPBES also defines a **'maintenance of options'** category for the yet-to-be-discovered or understood use of natural ecosystems and organisms (see Figure 1.1).

Even in economic and monetisable terms, not every dollar counts the same. For example, coastal fisheries account for less than 1 percent of the ocean economy as conventionally defined. However, this is most likely a significant underestimation of the sector's true economic importance. To more accurately represent the importance of the marine economy, one would also need to include employment for over 37 million artisanal fishers[92], and the ocean's provision of essential food for millions living in poverty along the coasts of the developing world, as well as for the 1 billion people relying on the ocean for most of their animal protein[93].

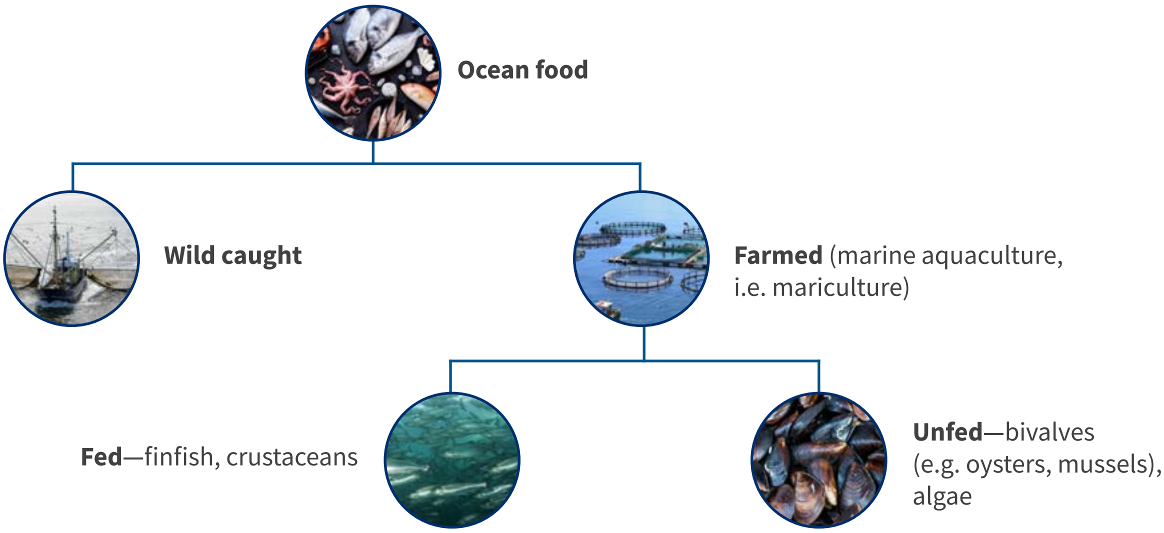
Most global economic activity either depends on the ocean, is based on the ocean or affects the ocean in some essential way. According to the Intergovernmental Panel on Climate Change (IPCC), 'All people on Earth depend directly or indirectly on the ocean and cryosphere'[94]. Some illustrative facts confirm this importance of the ocean for humanity: 50–80 percent of the oxygen comes from the ocean[95], 44 percent of the world's population lives within 150 kilometres of the coast[96] and 90 percent of all international trade involves marine shipping[97].

The ocean has a central role to play in global food security, but the way the ocean is currently used is not on track to deliver it

Earth's population, 2.5 billion in 1950, has grown to 7.8 billion in 2020 and is projected to peak in 2064 at about 9.73 billion[98]. It has been estimated that 470 million metric tons (MMT) of total animal protein will be required annually to feed the 2050 population[99]. The relative sources of land-based, ocean-based and lab-grown supply are not yet clear and will be highly dependent on the evolution of future technologies as well as human preferences. However, ocean-based food will almost certainly have a central role to play in global food security—it is healthy, its carbon footprint is low compared to land-based animal proteins[100], and it doesn't require extensive use of water or the conversion of land for agricultural use. See Figure 1.2 for the types of ocean food discussed in this report.

If the EAT-Lancet diet[101]—used here as a solid proxy for a globally sustainable and healthy model of nutrition—were globally adopted, 2050 fish and seafood production would need to increase by 60–118 percent over 2010 production levels (with the range depending on food waste reduction)[102]. This corresponds to a production increase from 109 MMT today to between 160 and 218 MMT by 2050 (in whole weight). These forecasts are currently being refined to assess more precisely the role of ocean food in feeding a 2050 planet[103].

Figure 1.2. Scope of Ocean Food Discussed in This Report



Source: Authors. Photo credits: Ocean food: Anna Pustynnikova/Shutterstock; Wild caught: Split Second Stock/Shutterstock; Farmed: Vladislav Gajic/Shutterstock; Fed: Konstantin Novikov/Shutterstock; Unfed: Dilara Mammadova/Shutterstock.

This is in stark contrast to current, business-as-usual (BAU) projections of seafood supply (Figure 1.3), which project a decline of capture fisheries from 80 MMT today to 67 MMT by 2050 due to the pressure of overfishing on some stocks and underfishing on others[104]. Finfish mariculture (marine aquaculture) is not projected to fill the gap, as it is seen as constrained by the availability of fish oil (FO) and fish meal (FM)—in other words, 'fishing fish to feed fish'. At reasonably probable future inclusion rates for FO and FM, annual finfish production is forecast to reach a maximum of only 14.4 MMT: around twice the current production—far short of what would be needed to fill the gap[105]. Bivalve mariculture (e.g. of mussels and oysters) does not require outside feed and therefore has a greater growth potential than wild-capture fisheries and farmed finfish, even in a business-as-usual scenario. A steady increase in bivalve production (aligned with the past 10 years' annual growth rate) therefore makes the biggest contribution to a projected overall doubling of mariculture production, from 29 MMT to 66 MMT in 2050.

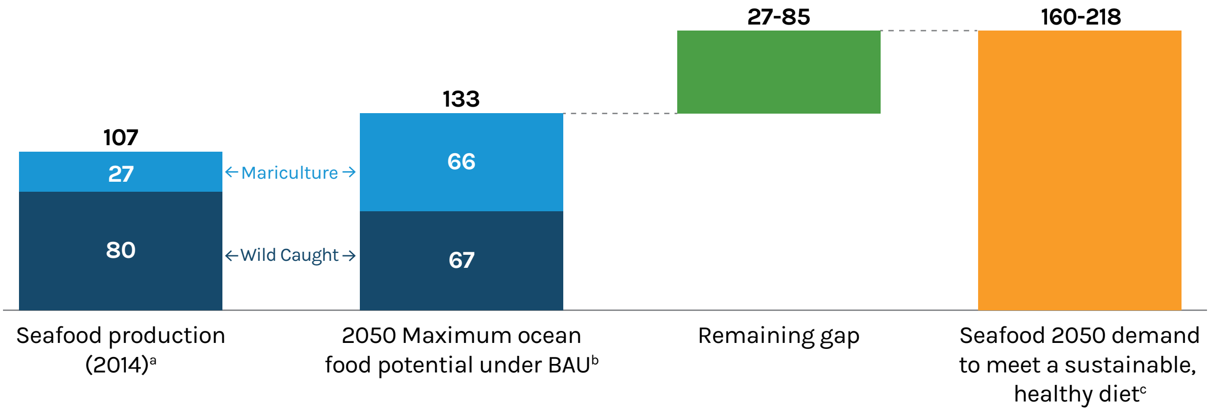
Summing these three potential contributions under a BAU scenario leaves a shortfall of up to 85 MMT (Figure 1.3).

The BAU scenario, of course, is not etched in stone. If properly and sustainably managed, capture fisheries could contribute about 98 MMT by 2050—over 40 percent more than the BAU projection[106].

In addition to this wild-caught potential volume, finfish mariculture can contribute higher yields once (partially) decoupled from FM/FO[107]. Mariculture must and can be done right. Unfed species (bivalves, seaweeds) are generally more benign to the environment, but barriers remain to higher production and consumption (e.g. the gap between perceived risk and actual risk)[108]. Finfish mariculture will require further technology development, and strict environmental regulations on antibiotic and effluent pollution, before it can produce very large volumes, presumably offshore, with lower local impacts and without reliance on fish-based feeds. Recent developments are encouraging; progress in both governance (e.g. the 'traffic light system' in Norway, which conditions production on environmental assessments) and technology (e.g. disease control, alternative feeds, etc.; see Section 1.3) is underway. Additionally, equity issues associated with mariculture must be attended to, ensuring the full inclusion of women, equal treatment of all ethnic and racial groups, adoption of safe labour standards and fair treatment of smallholder farmers[109].

Unfed mariculture, including seaweed production, is also currently greatly underdeveloped compared to its advantages and biological potential (see Chapter 2).

Figure 1.3. The Seafood Gap to a Healthy 2050 Diet under Business as Usual



Sources:

[a] Excluding seaweed. FAO, ed. 2018. The State of World Fisheries and Aquaculture 2018: Meeting the Sustainable Development Goals. Rome: Food and Agriculture Organization of the United Nations. http://www.fao.org/3/I9540EN/i9540en.pdf.

[b] Wild-caught fisheries' 13 MMT decrease by 2050 under BAU from Costello, C., L. Cao, S. Gelcich et al. 2019. "The Future of Food from the Sea." Washington, DC: World Resources Institute. https://www.oceanpanel.org/blue-papers/future-food-sea. For aquaculture 2050 BAU is obtained by summing the additional maximum potential for fed aquaculture under current feed constraints (+7.7 MMT) with an additional 28.9 MMT potential for shelled molluscs calculated by applying the 2005–14 global compound annual growth rate to the 2014–50 period (assuming continued linear growth as there is no feed constraint).

[c] Troell, M., M. Jonell and B. Crona. 2019. "The Role of Seafood in Sustainable and Healthy Diets." EAT-Lancet Commission, 24. https://eatforum.org/content/uploads/2019/11/Seafood_Scoping_Report_EAT-Lancet.pdf. These authors quote a range of 60% to 1,118% necessary production increase for 'Fish or seafood' over 2010 production levels. Numbers projected here are simplified by assuming that the ratio between freshwater and marine fish remains unchanged in 2050 versus the baseline year.

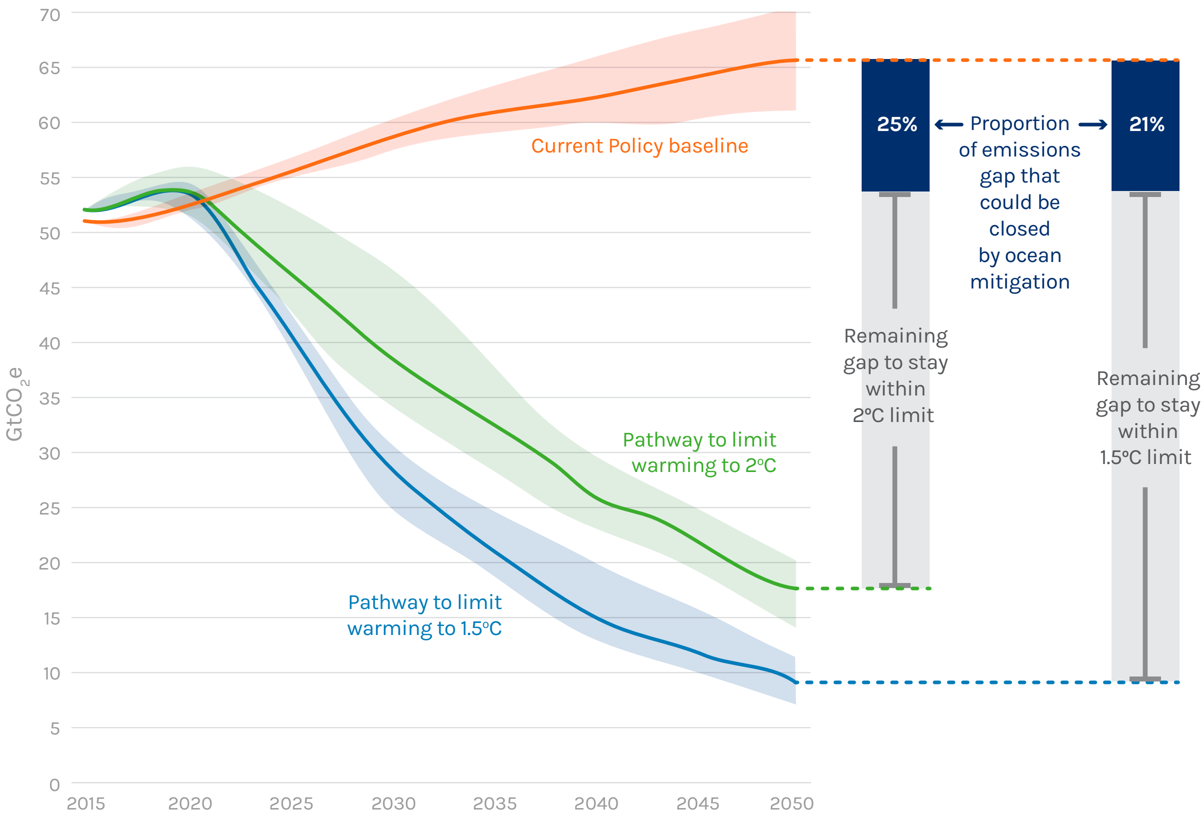
Ocean-based solutions are underappreciated and essential to fight climate change

The significant carbon mitigation challenge inherent in a 1.5°C future is well understood and documented[110]. Usually seen as victims of climate change, the ocean and its coastal regions also offer a wide array of potential options to reduce GHG emissions. A comprehensive review was undertaken as part of a report commissioned by the High Level Panel for a Sustainable Ocean Economy (Ocean Panel). The Special Report 'The Ocean as a Solution to Climate Change'[111] estimates that ocean-based climate solutions could reduce global GHG emissions by up to 4 billion tonnes of carbon dioxide equivalent (CO_2e) annually by 2030 and by up to 11 billion tonnes annually by 2050. This could contribute as much as one-fifth (21 percent) of the emission reduction required in 2050 to limit warming to 1.5°C and 25 percent for a 2°C target (Figure 1.4). Emission reductions of this magnitude are equivalent to the annual emissions from all coal-fired power plants worldwide or taking 2.5 billion cars off the road every year. These numbers correspond to an upper range based on strong political signals and investments.

The ocean-based options explored in this report include scaling ocean-based renewable energy generation (as a replacement for fossil fuel generation), reducing GHG emissions from marine transport (domestic and international), switching from emission-intensive land-based protein to low-carbon protein from the ocean, using seaweed as an alternative low-carbon fuel and feed for terrestrial activities, increasing the sequestration and storage potential of coastal and marine-based carbon stocks, and storing carbon in the seabed. These options did not feature prominently in the first round of nationally determined contributions (NDCs) communicated by countries or the long-term low GHG emission development strategies communicated to date under the Paris Agreement, but they offer island and coastal nations significant opportunities to consider in addition to land-based emission reduction measures[112].

Currently, these solutions are delivering significantly less than their full mitigation potential. For example, the ocean's renewable energy contribution totals less than 0.3 percent of total global energy production[113]. Alarmingly, not only is the carbon sequestration and storage potential of coastal and marine ecosystems

Figure 1.4. Contribution of Ocean-Based Mitigating Options towards the Emission Gap



Sources: UNEP 2018, Climate Action Tracker (2018), as adapted by Hoegh-Guldberg, O., et al. 2019. "The Ocean as a Solution to Climate Change: Five Opportunities for Action." Washington, DC: World Resources Institute. https://oceanpanel.org/sites/default/files/2019-10/HLP_Report_Ocean_Solution_Climate_Change_final.pdf.

not fully being captured through efforts to protect and manage these ecosystems but the degradation and loss of these ecosystems—mangroves at 0.21 percent per year[114], saltmarshes at 1–2 percent per year[115] and sea grass at 2–5 percent per year—is releasing significant emissions back into the atmosphere[116].

The ocean can catalyse a global transition towards more circular and regenerative practices in land-based economies

The 'ocean economy' is usually associated with purely ocean-based industries—shipping, fishing and so on. Nonetheless, almost all land-based industries rely on the services provided by the ocean. Perhaps the most difficult, and intriguing, part of the ocean economy puzzle concerns the chain reactions caused in global markets by changes in ocean-related production of fish, renewable energy or minerals. Everything is connected—a reduction of anchovy harvests in Peru affects the price of Scottish farmed fish, Chinese pigs and omega-3 capsules (all dependant on fish meal and fish oil, products extracted by drying and grinding up fish like anchovies)[117].

The ocean economy can thus not be viewed in a siloed 'blue' fashion. Moreover, this connectedness applies not only to what people remove from the ocean but also to what they put into the ocean. Over 80 percent of all global marine pollution originates on land[118]—all too often, the ocean 'serves' as the ultimate planetary sink. It absorbs 30 percent of anthropogenic (land-based) CO_2[119], 90 percent of excess heat caused by anthropogenic GHG emissions[120] and an estimated 9 to 14 MMT of plastic pollution per year[121]. Following the old fallacy of 'the solution to pollution is dilution', the ocean has been expected to absorb invisible pollution like nutrient runoff, heavy metals (e.g. mercury, cadmium), nuclear waste, pharmaceuticals, persistent toxicants (DDT, TBT, pesticides, furans, dioxins, phenols), sewage and personal care products.

Keeping the ocean functioning within the bounds of the 'safe operating space' for humanity can also catalyse profound and profitable changes in land-based systems: moving away from the 'blue silo' allows for the explicit connection between SDG 14 (conserve and sustainably use the oceans, seas and marine resources for sustainable development)[122] and the acceleration of SDG15 (life on land), as well as other SDGs often thought of as land-based, including SDG 12 (sustainable consumption and production), SDG 9 (sustainable infrastructure) and SDG 7 (affordable and sustainable energy).

The fate of the ocean is directly linked to a broader shift towards a circular economy[123] approach to consumer goods and industrial production—a system where resources are used continually, at their highest possible value added, and recovered or regenerated as efficiently as possible at the end of their service. It is also linked to a land-based transition towards renewable energies, and to improved land use practices in agriculture and in coastal development. But looking at it the other way around, the ocean could be a unique opportunity to advance the broader global agenda of sustainability while 'leaving no-one behind'.

As a compelling example, the ocean is now the principal driver of fundamental work on the plastic value chain. The unprecedented crisis of ocean plastic pollution is bringing scientists, businesses, governments and civil society together to look for solutions[124]. For instance, in October 2018 in Bali, 250 organisations, including many of the packaging producers, brands, retailers and recyclers, as well as governments and NGOs (altogether representing 20 percent of all plastic packaging produced globally) committed to eradicate plastic waste and pollution at the source. Following the plastic example, the wasteful agriculture system could be challenged by the sustainable ocean agenda, obliging it to accelerate the transition towards precision farming, less toxic fertilisers and pesticides, and the collection and treatment of human and livestock waste and wastewater.

1.2. Failing the Environment and the People: The Need for Urgent Action

Physical, geological, chemical, biological and ecological processes interact in the ocean in complex ways. Those processes and interactions have now been fundamentally altered by human activities, with concomitant changes to the services provided to people by natural ecosystems. For example, loss of biological diversity, major perturbations of biochemical cycles, and climate change each alter the functioning of ecosystems, and that in turn impairs or limits the benefits that ocean ecosystems provide to people.

As the rate of change in most socioeconomic areas has accelerated past any historical precedent in the first half of the 20th century, so have most earth system indicators—a phenomenon described as 'the Great Acceleration' (Figure 1.5).

There is also increasing strain on the ocean system: the 'blue acceleration'—humanity's expansion into the ocean for food, materials and space—has been unparalleled in history[125]. The direct consequences of these trends are exhaustively documented today (see details below).

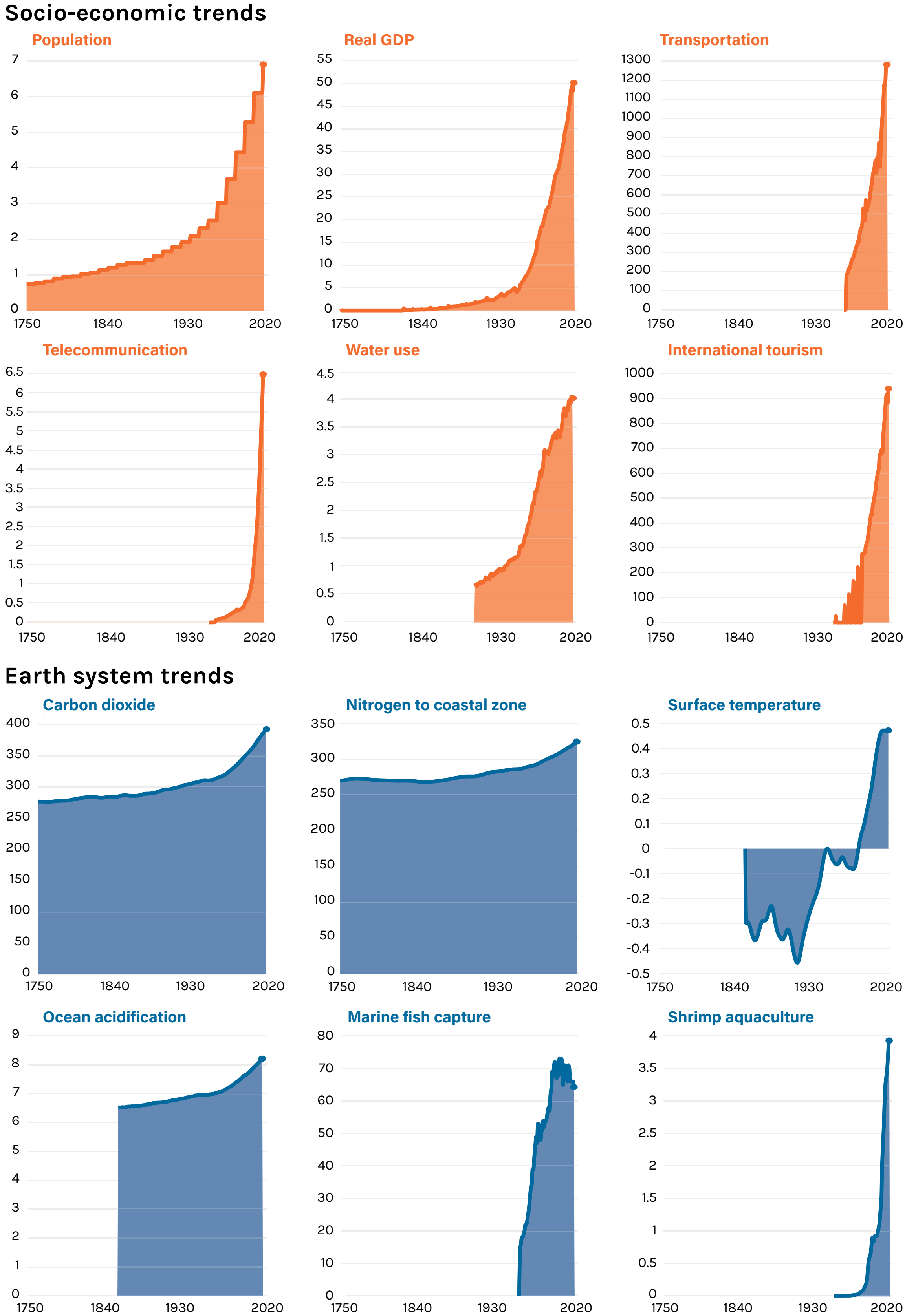
The direct footprint of human activity is visible almost everywhere. Sixty-six percent of the marine environment is experiencing significant cumulative impact by human actions[126]. Only 13 percent of the ocean area can still be classified as wilderness[127], and less than 3 percent of the ocean is unaffected by multiple human stressors[128]. For example, between 1970 and 2000, sea grass meadows declined by roughly 30 percent, mangroves by 35 percent and saltmarshes by 60 percent, whilst between 11 percent and 46 percent of marine invertebrates are threatened[129]. Below, the main stressors on the ocean caused by human activity are briefly described along with their directly observable consequences.

Overfishing. The direct over-exploitation of fish stocks and the unintended impacts of fishing gear on non-target species may be the most tangible manifestation of direct pressure from human activity[130]. This has been exacerbated by harmful fisheries subsidies (i.e. those directed at capacity expansion) as well as the effects of illegal, unreported and unregulated (IUU) fishing. Industrial and artisanal fishing fleets have been identified as the main driver of extinction for all classes of marine vertebrates except birds[131]. Estimates of overfished stocks range from 33 percent ('overfished' category in the Food and Agriculture Organization of the United Nations [FAO] database)[132] to 47 percent ('over-exploited or collapsed' category in the Sea around Us Project's classification)[133]. Higher trophic level species and predators such as sharks, tuna and billfish are especially depleted[134]. For example, a 2020 global shark survey found no sharks in almost 20 percent of the 371 surveyed reefs across 58 nations, with levels of shark depletion being closely correlated to poor governance, the density of human population and distance to the nearest market[135].

Open ocean diversity has declined by 10–50 percent over the past 50 years, a trend that has coincided with increased fishing pressure[136].

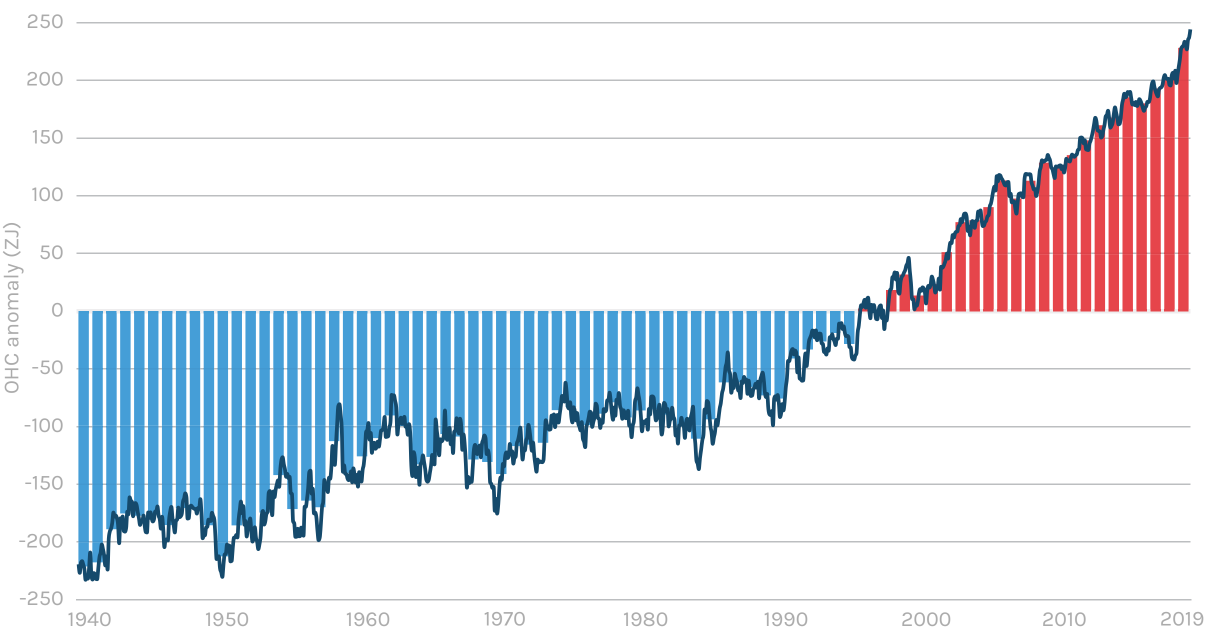
Climate change. The raw numbers are sobering: ocean waters have absorbed 93 percent of the excess

Figure 1.5. 'The Great Acceleration'



Source: Steffen, W., W. Broadgate, L. Deutsch, O. Gaffney and C. Ludwig. 2015. "The Trajectory of the Anthropocene: The Great Acceleration." Anthropocene Review 2 (1). https://doi.org/10.1177/2053019614564785.

Figure 1.6. 2019: Warmest Year in Recorded Human History for the World's Ocean



Source: Cheng, L., J. Abraham, J. Zhu, K.E. Trenberth, J. Fasullo, T. Boyer, R. Locarnini et al. 2020. "Record-Setting Ocean Warmth Continued in 2019." Advances in Atmospheric Sciences 37 (2): 137–42. doi:10.1007/s00376-020-9283-7.

heat caused by greenhouse gas (GHG) emissions[137] and sea surface temperatures have increased by 0.7°C since 1900[138]. New analysis confirms that 2019 was the warmest year on record for ocean temperature, and saw the largest single-year increase of the decade (Figure 1.6)[139]. The 12 years with lowest Arctic sea ice extent all happened in the past dozen years[140], and 2017 marked the lowest Antarctic sea ice extent on record[141].

Climate change generates stronger winds[142]. This intensification of surface winds has accelerated the global mean ocean circulation over the past two decades, especially in tropical regions[143]. These changes in ocean currents can affect not only weather patterns on land (e.g. the Gulfstream's influence on the European climate[144]) but also fisheries through, for instance, modification of larval dispersal[145] or changes in the intensity of coastal upwelling[146] (the movement of cold, nutrient-rich water to the ocean surface). These upwelling changes can enhance fishery productivity, as with anchovies along the coast of Peru; but if the upwelling is too intense, it can have the opposite effect, triggering 'dead zones' with insufficient oxygen to support fish and other marine life. Changes to ocean circulation are regionally variable. For example, the Atlantic Meridional Overturning Circulation (AMOC), which redistributes heat between tropics and higher latitude in the Atlantic, is one exception to the general pattern of speedier currents at the global scale. AMOC is 'very likely to weaken over the 21st century', according to the IPCC[147]. Considerable uncertainty remains, however: the IPCC cites a range of between 1 percent and 54 percent for AMOC weakening, depending on the warming scenario chosen[148].

Humanity's GHG emissions have also acidified the ocean by 26 percent since the Industrial Revolution[149], and climate change is impacting dissolved oxygen content in ocean systems across the globe (see more details about dead zones later in this section). The combined effects are putting additional stress on many coastal and oceanic species, including the shell-forming animals (corals, phytoplankton, zooplankton, bivalves and more) which represent the foundation of the marine food webs.

Habitat destruction. Key coastal habitats such as mangroves are being lost at an alarming rate: global mangrove cover has declined by around 25–35 percent (up to about 57,000 km^2 from 1980 to 2000)[150], largely due to land reclamation and conversion to aquaculture ponds and rice paddies[151]. This loss has resulted in reductions in fisheries and coastal food production[152], and increasing threats to species with a fragile conservation status. These coastal habitats help protect communities against life-threatening storm surge during tsunamis, typhoons, cyclones and hurricanes. Mangroves, sea grasses and saltmarshes are labelled 'blue carbon' ecosystems because they actively sequester and store organic carbon from the environment[153], meaning their loss increases emissions[154]. The seafloor habitats have also been significantly affected by destructive fishing gear and methods. Bottom trawling has destroyed cold water coral and sponge ecosystems, which will take centuries to recover[155]; dynamite and cyanide fishing has contributed to the decline of coral reefs[156].

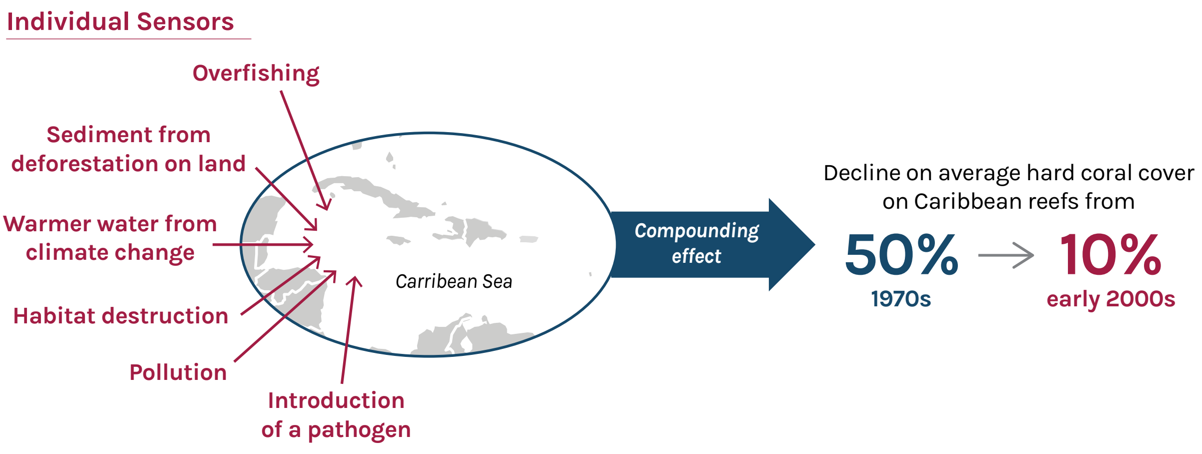
Plastic pollution. At least 700 species of marine life have been demonstrated to interact with plastic[157], with the main impacts occurring through entanglement, ingestion and chemical contamination from macroplastics. The annual flow of plastic into the ocean is predicted to nearly triple by 2040 to 29 million metric tons per year if no serious action is taken[158]. This number corresponds to an equivalent 50 kilograms of plastic for every metre of coastline worldwide[159]. There is also clear evidence that microplastics are ingested by a wide range of species, including marine mammals, birds, fish and small invertebrates at the base of the food chain[160].

Other land-based pollutants. Ocean ecosystems and marine life are damaged by many land-based pollutants, such as pesticides, antibiotics, parasiticides, pharmaceuticals, heavy metals, persistent organic pollutants and excessive amounts of nutrients such as nitrogen and phosphorus. For instance, in Southeast Asia, an estimated 600,000 tonnes of nitrogen end up in the ocean every year, discharged from major regional rivers[161]. Direct impacts vary considerably, depending on the pollutant, its amount and the presence of other stressors[162]. Impacts can include excess productivity that triggers dead zones (low- or no-oxygen; see details later in this section), reduced photosynthetic efficiency, chronic stress on marine organisms, cancer in animals, likely inhibition of reproduction and birth defects[163].

Invasive species. Discharge of untreated ballast water from ships is considered one of the major threats to biodiversity that, if not addressed, could have severe public health, environmental and economic impacts[164]. One cubic metre of ballast water can contain up to 50,000 zooplankton specimens[165] and/or 10 million phytoplankton cells[166]. With 10 billion tonnes of it transferred throughout the world each year[167], ballast water is one of the principal vectors of potentially invasive alien species[168].

Compounding stressors. In many occurrences these individual stressors locally compound one another with exponential consequences on ecosystems. For instance, coral reefs around the globe are exposed not just to overheating but also to overfishing and pollution. The decline of average hard coral cover on Caribbean reefs from 50 percent in the 1970s to 10 percent in the early 2000s, for example, was caused by the introduction of a pathogen killing an important herbivore (sea urchin), on top of decades of overfishing of herbivores and grazers (parrotfish and multiple other species of fishes) as well as predators essential to the integrity of the system, sediment from deforestation on land, warmer water from climate change, and physical destruction

Figure 1.7. Case Study: Compounding Stressors Leading to the Decline of Caribbean Reefs



Source: Authors, inspired by Jackson, E.J., M. Donovan, K. Cramer and V. Lam. 2014. "Status and Trends of Caribbean Coral Reefs: 1970–2012." Gland, Switzerland: Global Coral Reef Monitoring Network, International Union for Conservation of Nature.

and pollution from overdevelopment in coastal areas (see Figure 1.7)[169]. In Asian and Australian waters, the primary drivers are switched. For example, in 2016 the Great Barrier Reef experienced an unprecedented die-off of staghorn and tabular corals on a third of its reefs[170], caused by a record heatwave, with pollution playing a secondary role. Overall, the outlook for coral reefs is deeply concerning: annual severe bleaching (ASB) is forecast to affect 75 percent of all global reefs before 2070, even if the Paris Agreement carbon reduction pledges are followed[171]. With coastal overfishing endemic in most developing countries, the resilience of reefs to ASB events will be greatly diminished. With global warming of 1.5°C, coral reefs would decline by 70–90 percent, and virtually all (> 99 percent) would be lost at 2°C warming[172].

It should be noted, however, that large, remote coral reefs that are fully protected from extractive and abatable destructive activities (in fully protected marine protected areas) have proved to be more resilient to warmer water and other environmental stressors. Coupled with the finding that some strains of corals are becoming more tolerant of warmer waters[173], this suggests that it may not be too late to save coral reefs if strong action is taken to reduce carbon emissions[174] and create large, fully protected areas in the ocean.

Indirect effects can already be observed

When these pressures increase beyond a certain tipping point, the interconnected ocean system may no longer be able to provide the benefits people want and need. The combination of their effects can be unexpectedly severe and larger than the sum of their parts. If these stressors start compounding on a larger scale, potentially serious and fundamental indirect, ‘second order’ consequences occur, such as loss of biological diversity and abundance. Though analytically demanding in terms of attribution and measurement, such consequences are highly significant for the ocean’s future. Even more concerning is that indirect effects may fundamentally shift key parts of the ocean system from one state to another that is often functionally different (Figure 1.8). At this level, even sophisticated models and ‘data revolution’ tools can only suggest *what* might happen but not precisely *when* and *where*. Given what is at stake, these effects need to be considered in decisions, even if uncertainty is high.

Stratification. Ocean stratification occurs naturally when waters with different properties (temperature, salinity, density) form layers, which act as a barrier to mixing[175]. Usually, wind, currents and storms help mix the cold (deep) and warm (upper) layers[176]. Climate change disturbs this dynamic: rising surface temperatures exacerbate the layering and decrease the rate of mixing. This, in turn, decreases the amount of nutrients travelling up to surface waters, which further affects biological productivity, heat redistribution, carbon uptake and oxygen production. The data show that upper ocean stratification will be greater everywhere during the second half of the 21st century, indicating a more pronounced decoupling between the surface and the deeper ocean[177]. The areas most affected include the Arctic, the tropics, the North Atlantic and the northeast Pacific[178].

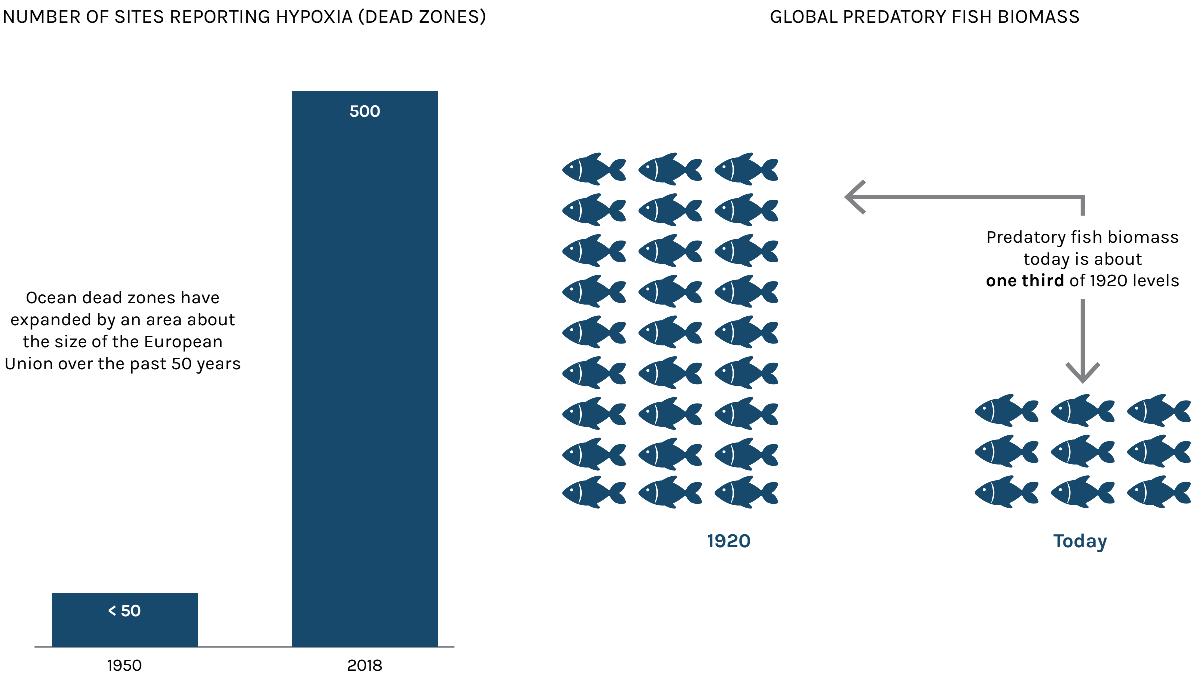
Deoxygenation. In the open ocean, deoxygenation is primarily caused by global warming: oxygen solubility decreases with increasing temperature, and less oxygen reaches the deep ocean layers because of stratification. In the past 50 years, the ocean’s oxygen content has decreased by 2 percent[179], and ocean models predict a further decline of up to 7 percent by 2100[180]. Oxygen-minimum zones in the open ocean have expanded by several million square kilometres[181].

In estuaries and other coastal systems strongly influenced by their watershed, oxygen declines can be linked to agriculture, sewage and the combustion of fossil fuels, which generate increased loadings of nutrients (particularly nitrogen and phosphorus) and organic matter[182]. An influx of nutrients causes an increase in microscopic algae, which ultimately die and decay, and the resulting decomposition process consumes oxygen, leading to oxygen depletion in the surrounding water. The Baltic Sea is a prime example of low-oxygen conditions caused by high nutrient loads from land runoff[183]. Oxygen decline in coastal systems is exacerbated by climate change (as in the open ocean) and by increasing nutrient delivery originating from increased precipitation[184].

Overall, around 700 sites worldwide are now affected by low-oxygen conditions—up from only 45 in the 1960s[185]. Deoxygenation can have far-reaching biological consequences. Larger fish species with high metabolic rates, including yellowfin tuna and swordfish, are especially vulnerable to deoxygenation, and there is evidence that the balance of marine life is starting to shift in favour of species that are more tolerant of low-oxygen conditions, such as microbes, jellyfish and some squid[186]. Low-oxygen conditions can also make animals more susceptible to pathogens and parasites, increasing morbidity and mortality from diseases.

Reduced biomass and biodiversity, and redistribution of species. Physical changes and overfishing have profound second-order consequences

Figure 1.8. Examples of Indirect Consequences of Compounding Pressures on the Ocean



Sources: Breitburg, D., L.A. Levin, A. Oschlies, M. Grégoire, F.P. Chavez, D.J. Conley, V. Garçon et al. 2018. "Declining Oxygen in the Global Ocean and Coastal Waters." Science 359 (6371). doi:10.1126/science.aam7240; Srokosz, M.A., and H.L. Bryden. 2015. "Observing the Atlantic Meridional Overturning Circulation Yields a Decade of Inevitable Surprises." Science 348 (6241): 1255575; Christensen, V., M. Coll, C. Piroddi, J. Steenbeek, J. Buszowski and D. Pauly. 2014. "A Century of Fish Biomass Decline in the Ocean." Marine Ecology Progress Series 512 (October): 155–66. doi:10.3354/meps10946.

for the biological ocean. The IPBES estimates that 'more than 40 percent of amphibian species, almost a third of reef-forming corals, sharks and shark relatives, and over a third of marine mammals are currently threatened with extinction'[187]. Overfishing disproportionately removes predators, which are replaced by shorter-lived and smaller species, and the food chain becomes much simpler, less dynamic and less resilient[188]. Predatory fish biomass today is about one-third of 1920 levels.[189] Warming and deoxygenation are predicted to cause a large-scale redistribution of global fish and invertebrate biomass by 2055, with a 30–70 percent increase in high-latitude regions and a drop of up to 40 percent in the tropics[190]. Loss of biodiversity leads to measurable decreases in ecosystem functionality, including the number of viable fisheries (non-collapsed), the provision of nursery habitats, as well as the filtering and detoxification services essential for water quality and the reduction of harmful algal blooms, fish kills and beach closures[191].

Sea level rise. Sea level rise results from a combination of thermal expansion caused by the warming of the ocean (since water expands as it warms) and increased melting of glaciers and ice sheets[192]. A range of positive feedback mechanisms makes predictions exceedingly complex. For example, the melting of glaciers accelerates their rate of flow into a warming sea. It has been assessed that the global average sea level has risen by about 16–21 centimetres since 1900[193], at an accelerating rate over the past two decades[194]. The future extent and level of potential damage from sea level rise is therefore the subject of intense research and debate. The IPCC frames the range of outcomes between the empirical record of similar events in the distant past, and much more cautious simulations from process-based computer models: 'Paleo sea level records from warm periods during the last 3 million years indicate that global mean sea level has exceeded 5m above present (very high confidence) when global mean temperature was up to 2°C warmer than pre-industrial (medium confidence)'[195]. Perhaps more relevant to climate policies than the slow rise over centuries to millennia is the risk of rapid melting of Antarctic or Greenland ice that could lead to sea level rise of several metres over a span of decades. The risk of such catastrophic events is notoriously difficult to evaluate based on observational records.

Phenomena such as deoxygenation and reduction of biomass and biodiversity are highly synergistic—one propels the other. It is not analytically feasible to predict precisely *when* and *where* these complex chains of events will occur. However, new 'big simulation' tools allow us to describe *what* might happen in any given ocean region[196]. Typically, these simulations show that while a single source of stress (e.g. overfishing, pollution) can do considerable damage, multiple and compounding sources can do worse by orders of magnitude[197]. Put simply, ocean risk is a function of how bad the stressors are, the degree to which they reinforce each other and the natural variability of the ocean they are affecting.

The 2019 IPCC report *The Ocean and Cryosphere in a Changing Climate* estimates that climate-induced declines in ocean health will cost the global economy US$428 billion per year by 2050 and $1.98 trillion per year by 2100 (Figure 1.9)[198]. These numbers encompass costs associated with declines in ocean health and services due to climate-change, overfishing, excessive nutrient loads and plastic pollution.

Of course, the synergy story has an upside as well. If each new layer of stress increases overall risk disproportionately, then the opposite is also true: for each layer taken away, the system becomes more resilient. This makes it possible to buy valuable time when dealing with long-term issues such as warming or acidifying waters.

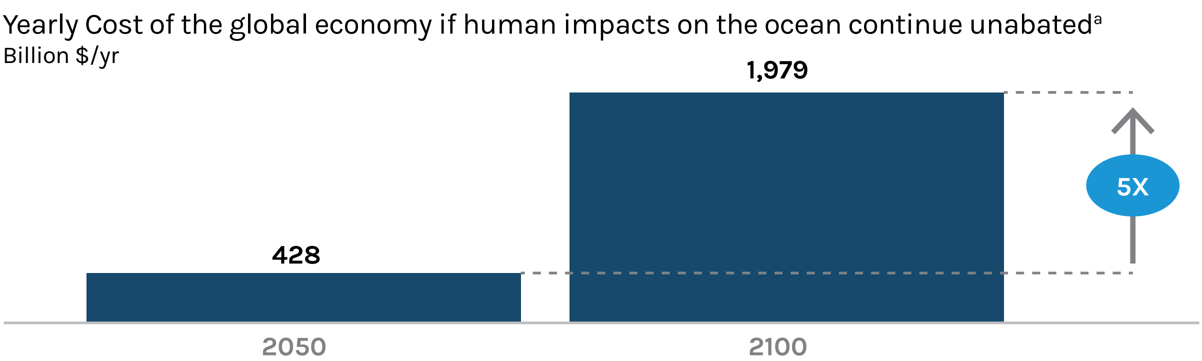
The decline of ocean health is threatening most ocean sectors

Insufficient action to reform the ocean economy and protect and restore ocean health can negatively impact ocean sectors that depend on a healthy, productive and resilient ocean or are directly exposed to its physical manifestations (e.g. sea level rise, waves, extreme events).

Wild-catch fisheries. Climate change will impact wild-catch fisheries in terms of both stock productivity (i.e. its potential sustainable yield) and distribution (i.e. its physical range). The IPBES states that 'climate change alone is projected to decrease ocean net primary production by 3–10 percent, and fish biomass by 3–25 percent' by 2100, depending on climate scenarios[199]. These global numbers mask even more significant variation in changes across stocks and regions. Poleward regions such as the North Atlantic and North Pacific are predicted to see a 30–70 percent increase in catch potential, while equatorial regions face a 40 percent decrease[200].

Where stocks decrease or move away from traditional fishing grounds, fishers must spend more resources to locate and catch them[201]. Conversely, any shifts to shallower water may make stocks easier for local fishers to catch but more vulnerable to overfishing. Overall, smaller-scale fisheries which rely on vessels with limited range and low technological capabilities are likely to be most vulnerable to shifts in range or migratory patterns[202]. The equity implications of longer travel and/

Figure 1.9. The Cost of Inaction on the Global Economy



Note: [a] Cost associated with declines in ocean health and services due to climate change, overfishing, excessive nutrient loads and plastic pollution.
Source: Pörtner, H.O., D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, K. Poloczanska, K. Mintenbeck et al., eds. 2019. IPCC Special Report on the Ocean and Cryosphere in a Changing Climate. https://report.ipcc.ch/srocc/pdf/SROCC_FinalDraft_FullReport.pdf.

or declining yields are pronounced, especially since artisanal fisheries provide the protein of last resource in many developing countries' coastal areas.

Regulatory constraints may also hinder fishers' ability to adapt, particularly if species move across management boundaries[203]. Depending on the chosen climate scenario, between 28–72 percent of current global fishery yields will shift across country boundaries by 2100[204]. In addition to economic impacts, the redistribution of catch potential is likely to increase the risk of conflicts among fisheries, authorities and communities. In the absence of a coordinated response, the compounding effects of overfishing and stock (range) shift could severely threaten future global fishery yields and profits[205].

With these conditions expected to change and levels of uncertainty to grow, more adaptive management of fisheries will be critical to a better future (e.g. through rights-based fishery or secure-access systems)[206].

- **Mariculture**. The overall potential of mariculture is likely to remain high under climate change. With careful planning, improvements in feed technology and the implementation of best practices for preventing or reducing negative impacts on ecosystems and communities, mariculture could offset long-term losses in food and income from capture fisheries in most countries that will experience losses in that sector. However, a study found that a severe climate scenario would create both gains and losses in the studied 180 cultured finfish and bivalve species[207]. Lower trophic species such as bivalves were affected disproportionately due to the compounding effects of shifts in temperature, chlorophyll and ocean acidification.

The Indo-Pacific region—China, India, Bangladesh and Indonesia—is particularly impacted; finfish mariculture could decline by as much as 30 percent in some areas, and the risks to bivalve farmers are even higher[208]. Many coastal residents in these regions depend heavily on seafood for employment and food security.

Anthropogenic pollution is already having an effect on mariculture operations. Apart from farmed species requiring pristine water conditions for optimal growth, the accumulation of anthropogenic pollutants, especially microplastic in farmed (and wild) species, is a significant concern[209]. This is especially true of non-fed mariculture species like bivalves[210], who feed by filtering suspended material—including the accidental microplastics—out of the water column.

Tourism. Sea level rise will erode and submerge tourism infrastructure and beaches, with many resorts sitting at less than 1 metre above the high-water mark[211]. In the Caribbean, a sea level rise of 1 metre is projected to endanger 49–60 percent of tourist resorts, damage or cause the loss of 21 airports and cause severe flooding of 35 ports[212]. In 2050, according to one estimate, rebuilding tourist resorts alone will cost the region US$10 billion to $23.3 billion[213]. In Venice, higher water levels are threatening building integrity, eroding the lagoon and subjecting the city to more than twice as many floods since 1960.

The tourism industry also will be hit by the loss of coral reefs. Coral reefs contribute $11.5 billion annually to global tourism revenues, benefitting more than 100 countries[214]. Coral reefs would be virtually all lost at 2°C warming[215], with serious impacts for tourism in Australia and small island developing states (SIDS) in the Caribbean and elsewhere[216].

Tourism is both a source and a victim of pollution[217]. Beach closures due to sewage pollution affect countries worldwide. Other direct forms of pollution impacting tourism include plastic waste on beaches, making them undesirable for tourists to visit. Indirect impacts of anthropogenic pollution on tourism also exist: the combined effect of elevated sea surface temperatures, excess fertiliser and increased nutrient runoff due to deforestation are potential causes of the explosive growth of sargassum seaweed[218] that is washing up on tourism beaches in the Caribbean, the Gulf of Mexico and West Africa, driving down hotel bookings in certain areas[219].

On top of these worrying trends, the COVID-19 pandemic is having severe impacts on coastal tourism, for example. SIDS are expected to experience a 7.3 percent fall in gross domestic product (GDP) given their tourism dependency, and this drop could be up to 16 percent in highly tourism-dependent SIDS like Seychelles or the Maldives[220].

Ports and supply chains. Severe disruptions due to extreme weather events can be expected. A 2013 study[221] finds that the supply chain consequences of compounding sea level rise, higher storm surges, increased cyclone intensity and destructiveness[222], wave regimes[223] and river floods of ports[224], coastal refineries and chemical plants could cause operational delays at a scale of billions of U.S. dollars per day[225], with incalculable effects on business cycles, supply chains and the overall operating risk of companies.

The risk to coastal communities is increasing

Major and irreversible shifts in ocean functionality threaten coastal communities and habitats in many ways—the current ocean economy system is far from delivering prosperity for all. Further, the effects of these shifts will be disproportionately felt by vulnerable, historically underrepresented and underserved communities in both developed and developing countries.

Flood damage. New research has demonstrated that extreme coastal inundation events are increasing, and in some regions increased chronic flooding has been observed[226]. Many small islands already face large, sometimes existential, flood damage, and damage from sea level rise could equal several percentage points of GDP in 2100[227]. Risk associated with floods and hurricanes are accentuated for the 100 to 300 million people living within coastal 100-year flood zones, as the loss of coastal habitats and coral reefs reduces natural coastal protection[228]. In Europe, annual damage from coastal floods is expected to rise from €1.25 billion today to €93–960 billion by the end of the century[229]. Without drastic changes towards climate-smart coastal development, major disruptions can be expected in addition to damages to coastal communities.

Risks to agriculture. Sea level rise will affect agriculture through land submergence, the salinisation of soil and fresh groundwater, and land loss due to permanent coastal erosion[230]. Countries heavily dependent on coastal agriculture, such as Bangladesh, are likely to experience reduced production and livelihood diversity, as well as greater food insecurity (Figure 1.10)[231].

Permanently displaced coastal populations. Rising sea level will be experienced not only as a long-term, gradual event but also as a series of extreme events caused by the compounding effects of spring tides, stronger and slower-moving hurricane surges, spring floods and land loss. Based on a scenario without effective climate change mitigation policies[232], a 1 metre rise in sea level would entail dramatic increases in the frequency of 100-year extreme weather events in cities such as Shanghai, New York and Kolkata (Figure 1.10). Some cities will have the means to adapt with major feats of engineering, but other areas will become unliveable, generating waves of displaced people in the context of disasters and climate change. Indeed, 88 million to 1.4 billion people are estimated to be at risk of displacement[233]. In the United States, 3 feet (~0.91 m) of sea level rise by 2100 threatens 4 million people[234]. The situation is particularly dire for SIDS, for whom raising seas can become an existential threat[235].

Ocean activities are currently not delivering on the social Sustainable Development Goals

If not properly regulated and managed, a growing ocean economy can lead to even greater economic inequality than already exists[236]. Benefits will continue to be captured by an elite and strong incumbents, whilst vulnerable and marginalised groups become even more exposed to economic, social and cultural impacts and displacements[237]. In this scenario, the ocean economy could have a net negative effect on progress towards UN Sustainable Development Goals (SDGs) such as no poverty, zero hunger, good health and well-being, and reducing inequalities (see Section 2.3 for a detailed

Figure 1.10. Impacts from Compounding Effects of Climate Change

A **1 m rise** in relative sea level increases the frequency of current 100-year flood events by:

40 times in Shanghai

200 times in New York City

1,000 times in Kolkata

Example: salt water intrusion in Bangladesh through floods and storm surges:

Annual median projected change in soil salinity **is +39% by 2050**

Sources: King, D., Z. Dadi, Q. Ya and A. Ghosh. 2015. Climate Change: A Risk Assessment. National Library of Medicine, National Institute of Health; Dasgupta, S., M.M. Hossein, M. Huq and D. Wheeler. "Climate Change and Soil Salinity: The Case of Coastal Bangladesh." Ambio 44: 815–26. https://doi.org/10.1007/s13280-015-0681-5. Images: Left: GenadijsZ/Shutterstock; Right: FotoKina/Shutterstock.

assessment of the link between SDG 14 (life below water) and the other SDGs.

Increasing inequalities. Global inequity is increasingly acknowledged as a substantial challenge to the ocean economy. Inequities are contrary to and will undermine progress towards the Sustainable Development Goals as they have contributed to a deteriorating ocean environment, with negative effects on human well-being primarily borne by the most vulnerable. Climate change risks aggravate existing inequity. The vulnerable and marginalised will be disproportionately affected by the effects of climate change. The lack of alternatives and high dependence on fish stocks for nutrition and income disproportionally expose the coastal poor to the effects of climate change[238]. Growing demand for fish feed can also exacerbate inequalities by diverting small pelagic fish like pilchards from domestic consumption for food, where such fish are a key component of the diet for many communities[239]. In addition, poor communities have fewer resources to respond to shifting fish stocks by changing gear types or travelling further to fish, as well as fewer resources to shift livelihoods altogether. Gender inequality is pervasive in many ocean industries overall, and climate change could be especially devastating for the most marginalised coastal women[240]. The international community's global ambition to 'leave no one behind' can only be realised through inclusive governance and the fair distribution of ocean benefits. An increased focus on equity will be instrumental for the legitimacy, effectiveness and sustainability of the ocean economy.

Food insecurity and malnutrition. Projected changes in fish distribution and abundance will put income, livelihoods, nutritional health and food security at risk in communities that rely on marine resources, such as those in the Arctic, West Africa and small island developing states[241]. Globally, climate change puts up to 3 billion people at risk of food and economic insecurity[242]. Food security and human health are also threatened by harmful algal blooms, with communities in areas without sustained monitoring programs and dedicated early warning systems most vulnerable to these risks[243]. Cultural diet changes in certain parts of the world, particularly Pacific island nations, are shifting diets away from healthy, local reef seafood towards imported, often highly processed, high sugar and fat foods. The results are rising malnutrition and increasing prevalence of non-communicable diseases[244].

Job safety and security. The isolation of ships at sea and the liability protection of vessel owners afforded by current flag state regulations serve to conceal human rights abuses, whilst labour protections are poorly enforced in many countries. Informal or unregulated economies and fishing activities, such as shellfish gathering or fish processing, face significant exposure to unregulated exploitation and disproportionally employ women[245] and marginalised groups[246]. Unreported catches and illegal activities can mask labour trafficking, peonage systems, unsustainable resource use and health and sanitary issues whilst simultaneously avoiding taxation and detracting from wider economic benefits[247].

BAU ocean industries development is likely to cause and exacerbate inequities across the spectrum of ocean sectors, and people with vulnerable marine livelihoods (who are more likely to be women, ethnic and racial minorities, migrants, youth and Indigenous People) are likely to be disproportionately affected. A new paradigm urgently needs to be embraced[248].

Human rights. Organised crime and human rights violations are a known plague within the ocean economy, especially the fisheries sector. Apart from the human impact, these crimes continue to have negative impacts on the environment as well as the global economy. The crimes can include, among others, tax crimes, money laundering, labour offences, drug trafficking and migrant smuggling. Many of these crimes can be associated with or facilitated by illegal, unreported and unregulated (IUU) fishing[249], which is estimated to account for 20 percent of the world's catch (up to 50 percent in some areas)[250]. These offences have been notoriously challenging to address due to jurisdictional disputes and inadequate or absent legal frameworks and enforcement. Attention has been drawn to this issue on an international level, with increasing understanding of the complexities of organised crime in the fishing sector. In 2008, the UN General Assembly requested that states assist in gathering more information on the connection between illegal fishing and organised crime[251].

1.3. Embracing Hope: The Building Momentum for a Sustainable Ocean Economy

When reading through the litany of threats to the ocean, two uncomfortable questions arise: Is the ocean so complex and damaged that it is *too big to fix*?[252] Is the only way out to immediately curtail most ocean activities? The answer to both is a decisive 'no'. A profoundly different mindset is emerging, in an unprecedented number of global initiatives through the G20 and G7, the Ocean Panel, the UN Ocean Conference, Our Ocean, the World Ocean Summits, the

UN Decade of Ocean Science, World Trade Organization meetings on ending harmful fishing subsidies, COP26 on climate, COP15 on biodiversity, the RISE UP Blue Call to Action (led jointly by NGOs and civil society)[253] and so on. Coastal nations, especially small island states (alternatively referred to as 'large ocean states')[254] are advocating for socially equitable and environmentally sustainable growth[255]. Civil society is realising the ocean's decline and vigorously endorsing governmental action to protect it: a 2020 survey found, for instance, that 92 percent of Japanese respondents supported the establishment of MPAs, 92 percent of U.S. respondents believed that 'ocean governmental regulations are necessary' and 92 percent of Indonesian respondents 'supported environmental conservation regulations to protect the ocean'[256].

In response to the growing pressures described in Section 1.2, innovations and trends are emerging that demonstrate through trial and error that alternatives are possible[257]. These 'niche innovations' can be geographical and/or sectoral spaces, where innovators coalesce in response to perceived pressures affecting the ocean. These niche innovations can be protected from market dynamics (through subsidies, soft money) or political interference (through regulation or location in the non-profit sector). This section identifies (non-exhaustively) seeds of change already sprouting and in need of careful nurture: celebrated in their beginnings, prioritised in policy and finance, and promoted publicly.

This section first looks at selected sectorial innovations and trends (in particular in fisheries, mariculture, energy, shipping and tourism) before identifying additional cross-sectorial ones (in data, ocean planning, finance, anti-pollution efforts and accounting).

Hopeful and promising sectorial trends and innovations

Sustainable fisheries. Three main trends will accelerate sustainable reforms:

- **The turning institutional tide.** Most national fishery ministries are now committed to the goal of maximum sustainable yields. Most, however, still struggle to attain that goal. In recent years, regional fisheries management organisations (RFMOs), long constrained by consensus decision rules, have finally been able to restore some tuna stocks, notably Atlantic bluefin tuna and southern bluefin tuna[258]. The plight of artisanal fishers is being more fully considered in fishery management plans, but this is tempered by the lack of catch and effort data from artisanal fisheries, which are often equal in size to industrial fisheries. Fish-dependent nations in Asia (e.g. Indonesia, Fiji, the Philippines, the Marshall Islands) and Africa (e.g. Mauritius, Seychelles) are committed to restoring the efficiency and equitability of their fisheries and/or have made substantial protected area commitments.
- **A data revolution.** Sound fishery management digital tools are now widely available, including vessel tracking, fishery simulation, registry and enforcement systems (e.g. satellite imagery, eDNA and drones). Philanthropically funded initiatives to study the ocean have mushroomed (e.g. REVOcean, OceanX). Market demand in the developed world for sustainably sourced fish has never been higher and can now be reliably serviced with chain-of-custody certification. Shortcomings in data availability are being addressed through new collection technologies (onboard cameras, scanners) and new data analysis and treatment methods. Lowering the costs of such technology and new models around sharing will be necessary to also benefit the broader base of small-scale fishers.
- **Asset turnover.** Many of the developing country fishing fleets are ageing as profits have been too low to fund depreciation. The fleets of Ghana, the Philippines and Senegal, for example, all have an average age of more than 30 years[259]. In the absence of capacity-related subsidies, many of these boats cannot be profitably replaced—if market discipline is maintained (no capacity subsidies or assistance, from either the country itself or foreign nations through loans and/or selling of fishing rights). In such cases, fishing capacity is allowed to drop, and the profits of remaining boats can slowly recover towards the maximum sustainable yield point; creating feedback effects that financially reward sustainable fishers.

Box 1.1 presents two inspiring case studies of fishery recovery (at national and international levels), demonstrating that sound measures properly implemented can lead both to restoration of fish stocks and economic and social gains.

Mariculture. Trends in marine aquaculture also point towards future sustainable expansion:

- **National priority.** China and Norway lead the development of large, next-generation offshore finfish farms (Box 1.2) which attempt to address issues of containment, disease control and nutrient efficiency. Archipelago nations, such as Indonesia and the Philippines, are exploring locally relevant approaches such as combined seaweed and low-trophic mariculture farms. National commitments to spatially explicit planning, streamlined permitting,

Box 1.1. Successful Fishery Recovery Can Happen: Two Hopeful Case Studies

The United States Sustainable Fisheries Act of 1996 (SFA), and amendment to the 1976 Magnuson-Stevens Fishery Conservation and Management Act or Magnuson Stevens Act (MSA), governs fisheries management in the U.S. exclusive economic zone (EEZ) (up to 200 miles offshore). It is widely credited with saving U.S. fisheries. The original MSA established the legal basis for many essential fishery management mechanisms, such as the permitting of vessels and operators, and the ability to restrict gear, access and periods of fishing. However, for the first 20 years, and despite language aspiring to 'sustainable fishing', it did not explicitly prevent overfishing. The SFA changed this decisively. Its most important features were mandates to (1) not only end overfishing but also recover overfished species to sound, fully documented population levels (usually about one-third of the estimated pre-fishing population) within 10 years (with certain exceptions), (2) require that fishing quotas (catch limits) be set for each fishery, based only on scientific evidence about what is biologically sustainable, and include accountability measures to adjust future quotas in the case that overfishing accidentally occurs, and (3) allow the use of rights-based fishery management approaches if appropriate for that particular fishery. The inclusion of specific timelines and accountability measures made all the difference.

These amendments were highly successful. Forty-three fish stocks have been rebuilt since 2000, and over two-thirds of overfished stocks have been rebuilt or begun rebuilding since 1996. Revenue from 1996 to 2010 is up 54 percent in real terms[a]. The key features—reliance only on scientific evidence, use of rights-based approaches, strict catch limits and accountability measures, and the 10-year rebuilding plans—have been widely copied by fishery managers worldwide.

The law enjoys considerable support from the commercial fishing community and has generally held up well to inevitable pressure to extend deadlines for rebuilding stocks, relax catch limits and monitoring requirements, and limit the influence of science. Support for the law reflects the fact that stocks are rebuilding and fishers have input into the process, but especially because fishers' long-term incentives are aligned with their short-term incentives. The approach also combines national standards with regional tailoring. Regional fishery management councils propose management plans for each fishery that take into account local knowledge and factors but must also satisfy strict national standards.

The Parties to the Nauru Agreement (PNA) include the Federated States of Micronesia, the Republic of Kiribati, the Republic of the Marshall Islands, the Republic of Nauru, the Republic of Palau, the Independent State of Papua New Guinea and the Solomon Islands. Because these nations' mostly contiguous EEZs hold considerable fishery resources (especially tuna), they have developed a uniform management structure that prioritises resource sustainability and transparency[b].

The agreement most prominently features three major arrangements[c]:

1. A regionwide register and monitoring of fishing vessels, with trackers on each boat.
2. No transshipment at sea, mandatory daily catch and effort reporting, regular logbook maintenance, 100 percent onboard observer coverage and an electronic data transmission device that provides position and catch information.
3. No fishing in the high-seas pockets between PNA nation EEZs, no fishing on floating aggregation devices between July and September, and mandatory retention of any bigeye, yellowfin or skipjack tuna caught.

The resulting comprehensive data collection makes it possible to set up and enforce the Vessel Day Scheme—a type of fishing quota that allocates 'allowed days of fishing' to individual vessels. Based on a scientific stock assessment, an overall 'days of fishing' effort is determined (44,033 in 2019 and 2020)[d] and appropriated to the PNA countries[e]. The countries can then sell their allocated fishing days to fishing vessels, resulting in sizable revenues for the PNA countries—nearly US$400 million in 2015[f]. The fishing days are tradeable between countries, which helps optimize fishing across the entire PNA territory—an important feature in managing highly migratory tuna stocks. It also ensures that the fishery's benefits are shared by all PNA countries, regardless of where the tuna happen to be in any given year[g].

The agreement has increased revenue for the PNA countries while maintaining sustainable, science-driven harvesting practices. It has stabilised the stocks, provided the PNA (and other) nations with the lasting value derived from a well-managed fishery and has become a model for other ocean states. In 2012, this led the PNA skipjack tuna fishery to become certified by the Marine Stewardship Council, making it the world's largest independently certified tuna fishery[h].

Sources:

[a] *Natural Resources Defense Council, Conservation Law Foundation, Earthjustice, Ocean Conservancy, Oceana and Pew Charitable Trusts. 2018. "How the Magnuson-Stevens Act Is Helping Rebuild U.S. Fisheries." https://www.nrdc.org/sites/default/files/magnuson-stevens-act-rebuild-us-fisheries-fs.pdf.*

[b] *Parties to the Nauru Agreement (PNA). n.d. "Nauru Agreement Concerning Cooperation in the Management of Fisheries of Common Stocks (As Amended April 2010)." https://www.pnatuna.com/content/nauru-agreement. Accessed 13 August 2020.*

[c] *World Wildlife Fund. 2011. "Parties to the Nauru Agreement (PNA)." http://awsassets.panda.org/downloads/factsheet_7.pdf.*

[d] *"Purse Seine VDS TAE for 2018–2020." 2017. Parties to the Palau Arrangement, 22nd Annual Meeting, Majuro, Marshall Islands, 5–7 April. http://www.pnatuna.com/sites/default/files/Purse%20Seine%20VDS%20TAE%20for%202018-2020_0.pdf.*

[e] *Pacific Islands Forum Fisheries Agency. n.d. Introduction. https://www.ffa.int/vds. Accessed 6 May 2020.*

[f] *PNA. 2016. "Behind the Scenes Work Makes PNA's Vessel Day Scheme a Success." https://www.pnatuna.com/node/373.*

[g] *International Union for Conservation of Nature (IUCN). 2015. "Parties to the Nauru Agreement (PNA): Interview with Maurice Brownjon." https://www.iucn.org/content/parties-nauru-agreement-pna-interview-maurice-brownjon.*

[h] *Marine Stewardship Council. 2016. "PNA Tuna: Small Islands, Big Opportunities." http://pna-stories.msc.org/.*

rigorous operating standards and state-supported R&D are likely to further accelerate mariculture.

- **Improvement in fish meal/oil alternatives' availability and price.** The conversion of former biofuel or ethanol fermentation facilities to algae production (in places like Brazil or the U.S. Midwest) would scale up production so significantly that price points for omega-3 fatty acids as FM/FO alternatives and proteins could tumble (Box 1.2). Given the problems in the current biofuel markets, this could happen soon, and with considerable government support to prevent the stranding of these major industrial assets. Insect-based fish feeds also are attracting increasing attention, creating a source of revenue out of food waste (insects such as black soldier fly larvae can be grown out of food waste and be used to feed farmed fish)[260].
- **Progress made on limiting environmental impact of finfish mariculture.** Apart from feed, the main challenges of mariculture are (1) fouling of the water column and sea floor, (2) parasites (sea lice) that migrate to native (wild) species, (3) leakage of antibiotics used to (over)treat diseases and (4) the escape of non-native (and/or genetically modified) species. New technologies offer some promise. Remote video-controlled feeding systems can reduce food waste; parasites can be controlled drug-free through the addition of cleaner fish[261], lasers, electric fences and sudden changes in temperature[262]; disease resistance can be boosted with selective breeding[263]; control systems such as the Norwegian 'traffic light' system can control the growth of farmed salmon[264]; and rigid-structure caging systems can reduce escapes. Finally, the combination of bivalves and seaweed into multi-trophic farms is a promising approach to limit some impacts of finfish farming[265].

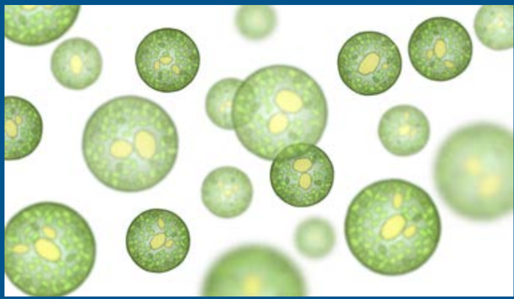
Accelerating ocean-based renewables. Offshore wind is an increasingly mature and competitive technology, but other ocean-based renewable energy sources are also actively being explored: energy extracted from waves and tides, from salinity and temperature gradients (e.g. by ocean thermal energy conversion or by

Box 1.2. Examples of Mariculture Tech-Driven Innovations

Credit: SalMar.

SalMar's Ocean Farm 1 is one of the largest offshore marine mariculture pens. Built in China and deployed in Norway, the 110-metre-wide-structure is predicted to be able to hold over 1 million salmon.

Apart from its enormous size (250,000 cubic meters), it is able to withstand 12-metre waves and is equipped with over 20,000 sensors monitoring the well-being of the fish.



Credit: Perception7/Shutterstock.

Grown by feeding sugar derived from sugarcane to algae in a fermentation tank through a special fermentation process, the algae turn the sugar into omega-3 oil, which can be (and is being used as) a replacement for fish oil in fish feed.

A frontrunner in this space is Corbion's DHS Algal prime, managing to save 40 metric tons of forage fish per ton of DHS Algal prime. Algal prime is already produced at a commercial scale, and with prices falling its algae omega-3 oil is at price parity with fish-derived omega-3.

DSM has partnered with Evonik to develop a similar algae-based solution, called Veramaris. They claim one ton of Veramaris algal oil is the equivalent of 60 tons of avoided wild-caught fish.

heat pumps for heating and cooling), and floating solar photovoltaic systems are beginning to emerge in marine environments[266]. Three major factors are encouraging the growth of ocean renewables:

- **Increasingly competitive electricity cost.** The levelised cost of electricity (LCOE) for offshore wind was $124–$146 per megawatt-hour (MWh) in the United States in 2017 and somewhat less in Europe[267]. Recently, auctions in the European market have seen contracts drop to about $50/MWh[268], which is highly competitive with other sources of electricity. Low cost of capital drives down LCOE for offshore wind, and economies of scale are significant, with costs declining at 18 percent per doubling of capacity[269]. Non-wind sources are largely uncompetitive today, with LCOE often above $250/MWh. Wave energy and ocean thermal energy conversion are capital intensive and unlikely to scale below $150/MWh and $70–$190/MWh[270], respectively, making them most useful for very specific applications such as for small island nations currently reliant on imported fossil fuels.
- **Rising global investments in offshore wind.** The ebb and flow of projects responding to policy has resulted in volatile global investment volumes (ranging from $30 billion to less than $15 billion in the past five years), but the overall trend is bullish. With decreasing offshore auction prices, the increasing water depth of projects, increasing turbine capacity and declining LCOE, global investments are nearly certain to increase—especially as Europe's commanding lead is challenged by Asia, Australia and even the Middle East in the years to come[271] (see Box 1.3).
- **Declining environmental impact.** There is growing consensus that offshore wind farms can be built without significantly damaging the environment, if proper planning and mitigation measures are put in place to address bird strikes, construction and operation noise, and sea floor damage[272]. The carbon mitigation benefits of ocean-based renewable energy production are significant and accrue back to ocean health and functionality.

Box 1.3. Offshore Wind in Vietnam

The southern coast of Vietnam has demonstrated technically feasible wind potential, with average wind speeds of 7–11 metres per second. Faced with gradually depleting hydro and fossil fuel energy sources and burgeoning demand, the country plans to install 6.2 gigawatts (GW) by 2030. As a major first step, a site survey licence has recently been issued for the 3.4 GW Thang Long wind project offshore from Ke Ga Cape—the world's largest wind project, located in a 2,800 km^2 area 20–50 kilometres offshore from Binh Thuan Province. This is the first step towards a US$11.9 billion, six-phase build-out designed to take optimal advantage of progressing Mitsubishi and Vestas turbine technology between now and 2026. The first 600 MW phase is expected to comprise 64 turbines at a best-in-class capacity of 9.5 MW and to be operational in 2023.

The project is emblematic of the special financial and operational conditions in developing countries. On the downside, developers generally are on their own with development costs, and projects win or lose on strict market terms. On the upside, the natural conditions are often perfect, and the onshore infrastructure/offtake facilities and supply chains are often new and up-to-date.

Shipping, often considered as a traditional, slow-moving sector, is experiencing a real revolution:

- **Shipping decarbonisation momentum.** The International Maritime Organization's Energy Efficiency Design Index requires ships built after 2022 to be at least 50 percent more efficient over 2008 levels[273], and total shipping GHG emissions to be reduced by at least 50 percent in 2050[274]. The industry is now actively working and collaborating on this agenda. For instance, Mærsk, a leading shipping company, is estimated to have invested several billion U.S. dollars between 2014 and 2019 in researching carbon-free shipping technologies[275]. The efforts are also focusing on addressing the difficult problem of collaboration: the 'Getting to Zero Coalition' convenes more than 100 companies and shipping-related stakeholders (e.g. ports) to develop 'commercially viable zero emission vessels, powered by zero emission fuels by 2030'[276]. The 'Green Maritime Methanol consortium' is exploring use of methanol as a shipping fuel[277]. Another cross-industry collaboration—Project ZEEDS—aims to create the 'zero fuel station of the future'—green ammonia fuel stations at sea that are powered by surrounding offshore wind farms (see the prologue of this report). Zero-carbon fuels are still at a very early stage for long-haul trips, but recent advances in battery technology have allowed short-haul ships—mostly passenger and car ferries in developed countries—to become electrified (see Box 1.4)[278]. Finally, on the energy efficiency front, optimised hull, propulsion and (existing) engine designs could deliver energy efficiency improvements of 30–55 percent compared to current fleets[279].
- **Ballast water treatment improvements.** In 1991, the 'International Guidelines for preventing the introduction of unwanted aquatic organisms and pathogens from ships' ballast water and sediment discharges', developed by the Marine Environment Protection Committee (MEPC)[280], set the stage for ballast water control. These standards have been followed by the 2017 Ballast Water Management Convention (BWM)[281], which requires ships to treat their ballast water by 2024[282]. The BWM has been supported by the GoBallast program, a global partnership of—among others—the Global Environment Facility (GEF), the IMO and the UN Development Programme (UNDP) aimed at reducing global ballast water pollution.
- **Improved port management.** The World Port Sustainability Program is designed to 'enhance and coordinate future sustainability efforts of ports worldwide and foster international cooperation with partners in the supply chain'[283]. On a national level, many ports are leading the way towards becoming more sustainable. The Port of Rotterdam's €5 million 'Incentive scheme for climate-friendly shipping' aims to make the port a leader in carbon neutrality[284]. A joint project by the Port Authority of Bari (Italy) and DBALab uses 'artificial intelligence for environmental monitoring and prediction' of the port's activities. The program's display environmental and port activity data allow operators to minimize the port's environmental footprint[285].

Successful coastal/marine conservation initiatives.

- **Restoration**. 'Soft' coastal approaches using tidal marshes, mangroves, dunes, coral reefs and shellfish

Box 1.4. Decarbonising Short-Haul Shipping: Electric Ferry

The Danish towns of Fynshav and Søby are connected by an electric ferry 60 metres long and 13 metres wide. The relatively short trip length of commuting ferries facilitates the use of batteries and electric engines. Since the first electric ferry was put in service in Norway in 2015, the number of electric ferries operating in the country has been rapidly increasing and will reach between 60 and 70 in 2021. Also, cities in the United States, Canada and Denmark have concrete plans (or even orders) to electrify their car and passenger ferries.

Source: Ellsmoor, J. 2019. "The World's Largest Electric Ferry Has Completed Its Maiden Voyage." Forbes, 18 August. https://www.forbes.com/sites/jamesellsmoor/2019/08/18/the-worlds-largest-electric-ferry-has-completed-its-maiden-voyage/. Photo: Erik Christensen, Creative Commons Attribution-Share Alike 4.0 International.

reefs are increasingly part of coastal defence. Sixteen thousand acres of tidal marshes in San Francisco Bay are under restoration, and the Mississippi marshlands are under restoration to protect New Orleans and southeast Louisiana from storm surges. The Netherlands and Belgium combine 'hard' solutions (e.g. seawalls, dykes, sluice gates) with 'soft' restoration, with the latter showing highly efficient results[286]. In the Belgian Scheldt estuary, up to 4,000 hectares of historically reclaimed wetlands are being converted back into floodplains; when finished in 2030 at a cost of €600 million, this will alleviate a 2100 yearly risk of flood damage estimated at €1 billion[287]. In Southeast Asia, mangrove forest plantations are being considered as protection against storm surges[288], but restoration projects are small compared to the area already lost. In cities as diverse as Amsterdam, Abidjan and Lagos, beach and dune barriers are being built as crucial defences against coastal flooding[289].

- **Protection.** Marine protected areas provide levels of protection ranging from strict 'no-take' to more permissive 'sustainable extraction' (see MPA guide in Figure 2.5). If properly sized, sited and delineated, they can generate multiple benefits. The strongly protected 'no-take' zones, for instance, have been shown to restore fish stocks by a factor of up to six times within the area[290]; to support ecosystem complexity, health- and associated ecosystem services[291]; to help with climate resilience[292]; to reduce carbon released from seabed floor[293]; to increase ecosystem resilience[294]; and to provide pristine ocean areas important to many cultures around the world.

- As of today, the Convention on Biological Diversity (CBD) estimates, 14.4 percent of national waters and 5.7 percent of the global ocean are protected[295]. However, only 2.4 percent of the ocean can be considered to be in fully protected MPAs[296]. Too often, MPAs are categorised as environmental measures at odds with economic interests (starting with fisheries).
- When full protection cannot be achieved, 'extractive MPAs'—defined as ocean areas subject to some restriction on use and/or extraction—can represent a viable form of protection for many countries with coastlines (>75 percent of countries in 2013)[297]. Properly designed, they can be effective in protecting key coastal habitats, and they may represent an underused means to block particularly destructive coastal land uses and resource-extraction practices.

Structural changes across ocean economy sectors

This section reviews recent progress in ocean data, ocean planning, finance, anti-pollution efforts and accounting of the ocean economy.

The ocean data revolution. The technology is here now. It is now technically possible to sample the ocean on its true spatial and temporal scales with a remote-sensing network covering the physical, biological, ecological[298] and chemical properties of the global ocean surface (although full coverage remains far off). From the proliferation of sensors and platforms (Argo floats[299], REMUS[300], Wave Glider[301]) and satellites (from SeaSat onwards) to cabled observatories[302] and acoustic modems, remote sensing and transmission of data from a variety of platforms is becoming an 'always on, always connected'[303] operating system. The connection of intelligent devices into an 'Internet of Things' is moving from land to sea, analysing data ranging from invasive species in bilge water to nutrients in river deltas, allowing for an ever-more complete picture in near real time—the holy grail of adaptive management. The open-access platforms necessary to store, share and process the innovation are technically available (and in broad use in many cloud-based data systems), but their application in the ocean realm is still lagging behind (see Section 3.2 for in-depth discussion).

Data processing is keeping pace with the sensing revolution. Processing capacity has increased 1 trillion times in the past 50 years, making it possible to build massive dynamic model simulations ranging from cosmological galaxy formation[304] to weather, climate prediction and hurricane prediction. The implications for ocean governance, management and economic development are profound.

Growing traction on ocean planning. The safety issues associated with multiple uses in a turbulent ocean environment (e.g. stationary wind farms or mariculture facilities vs. cargo, fishing and navy shipping lanes) are complex and a major cause of regulatory delays today. The regulatory difficulties of securing long-term, reliable permits and access rights are hurting the mariculture industry. Carbon- and offset-financed restoration projects are hard to structure without long-term title protections. Open access for all interested parties is the primary driver of overfishing in the developing world. On land, nobody would expect investors to deal with the legal and regulatory uncertainties of such an open-access system.

At the same time, the technical hurdles to delineating, monitoring, and enforcing access rights in a remote ocean are no longer applicable—the remote-sensing revolution offers multiple alternatives to expensive patrol-based enforcement schemes. For example, Caribbean protected area managers and technologists have jointly developed low-cost acoustic sensors that identify violating vessels[305]. Another example is Global Fishing Watch[306], which visualises, tracks and shares data on global fishing activities in near real time.

As a result, several regions (northeast United States; Netherlands/North Sea; Baltic Sea; Norway; Xiamen, China; and the Australian Great Barrier Reef) have broken down siloed management practices in favour of more integrated spatial planning. Xiamen, for example, has pioneered a spatially explicit approach to coastal management since 1994, with a 40 percent improvement in socioeconomic benefits from its marine sectors[307]. Hundreds of territorial user rights for fisheries (TURFs) areas are being set up across the globe to protect community fisheries in multiple developing countries (e.g. Chile, Indonesia, the Philippines), with emerging evidence of recovering stocks, and increasing catches and profits[308]. The Baltic Sea states have coordinated across borders and sectors to implement a science-based planning strategy and have been rewarded with the return of predators and birds as well as restored fish stocks in the past 20–30 years[309].

The ocean as the new investment opportunity. The tide is turning on ocean investment. In a recent Credit Suisse survey[310], 72 percent of investors ($n = 200$) classified the sustainable ocean economy as 'investable'. Several sustainable ocean economy private investment funds have been established recently: Sky Ocean Ventures, Althelia Sustainable Ocean Fund, Katapult Ocean, Ocean 14, BlueInvest Fund, Blue Oceans Partners and Fynd Ocean Ventures just to name a few. For more mature technologies such as wind energy, investments have also become sizeable offshore: 2018 investments in new offshore wind farms in Europe totalled €10.3 billion, 24 percent of total new power investments in that year[311].

International funding for sustainable innovation includes a 2019 proposal for an IMO-administered US$5 billion fund to 'accelerate the R&D effort required to decarbonise the shipping sector and to catalyse the deployment of commercially viable zero-carbon ships by the early 2030s'[312]. Also in 2019, the Asian Development Bank launched the Action Plan for Healthy Oceans and Sustainable Blue Economies for the Asia and Pacific region, with committed funding of $5 billion from 2019 to 2024 to finance and provide technical assistance for ocean health and marine economy projects in the region[313].

Unprecedented momentum in the fight against land-based pollution. Ocean pollution reforms are on different tracks. For plastics, the ocean is a major driver of global movement from linear to circular material management systems on land. For nutrients, pesticide runoff and industrial pollution, ocean interests have not yet reached the same level of influence, explaining a reform agenda lagging behind.

The transformation of the current linear plastic value chain to a more circular one represents enormous potential economic value, with estimated potential materials savings worth hundreds of billions of dollars per year[314], together with significant co-benefits for the climate (9.3 gigatonnes [Gt] of CO_2e in 2050—equivalent to eliminating transportation emissions), and employment upsides[315]. A recent comprehensive modelling exercise concluded that solutions available today to industry and governments—if massively deployed—could reduce annual land-based plastic leakage into the ocean by around 80 percent by 2040, compared to a business-as-usual scenario, and also help advance other societal, economic, and environmental objectives[316].

The crisis is now forcing the hand of plastic resin manufacturers, converters, and consumer brands. New consumer brand commitments to 'plastic neutrality' and recycling-friendly design are proliferating. The plastic industry as a whole is increasingly recognising its extended responsibilities for the entire product lifecycle and exploring cooperative schemes to improve waste management and collection. Over 95 plastic packaging policies and laws were signed in the United States, Europe and Asia from 2010 to 2019; and the New Plastics Economy Global Commitment had over 400 signatories, including from investors, innovators and NGOs. Cumulatively these commitments still fall far short of solving the crisis—but they represent only the beginning of what could become a comprehensive redesign of the plastic economy[317].

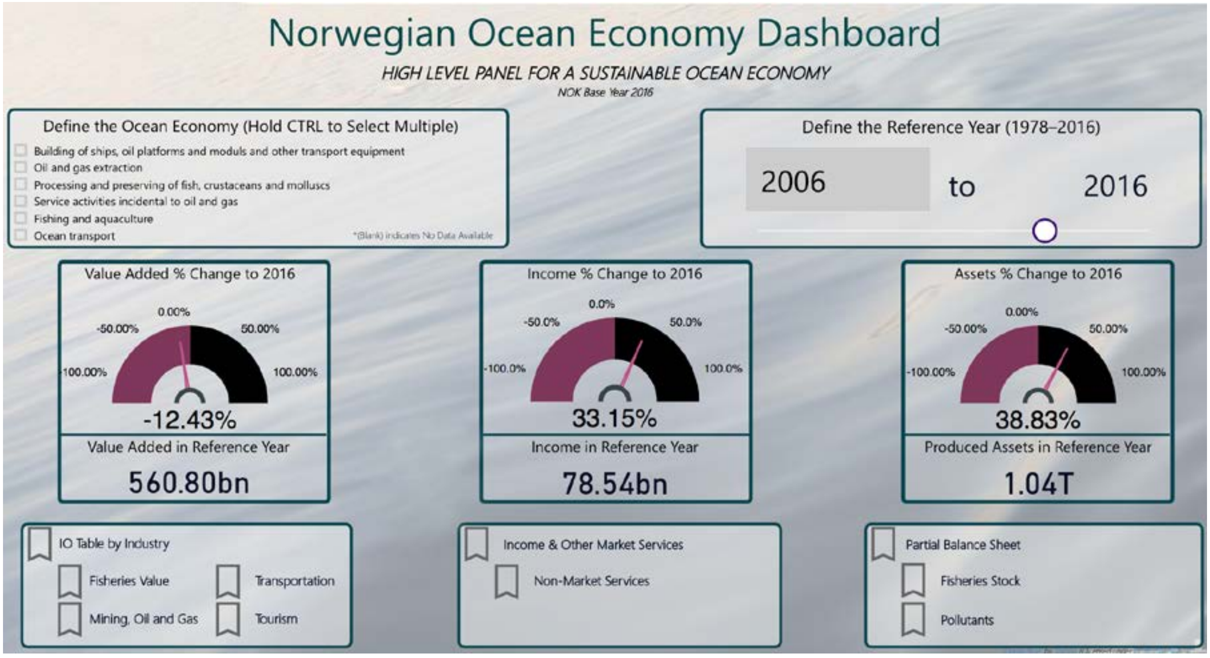
New, more holistic ways to account for the ocean economy are now available. Today's economic policy is concerned with outcomes and sustainability, not simply managing monetary inflation—'21st century progress cannot be measured with 20th century statistics'[318]. The System of Environmental Economic Accounting is being updated to include ecosystem accounting; there is discussion of revising the internationally agreed System of National Accounts to focus on sustainability[319].

The most fundamental remaining accounting challenge is the monetisation of ocean and other natural assets—an essential input. The international standards for national accounts—the 2008 System of National Accounts (SNA)—provides little guidance for doing so. But methods for the valuation of non-produced or natural assets do exist[320], including a 'Capital Asset Pricing for Nature' software package[321]. The Inclusive Wealth Index (2012) of the UN Environment Programme (UNEP), adopted by 140 countries, is piloting the measurement of natural capital[322], and many partnerships aim to develop technical capacity, such as the WAVES (World Bank), BIOFIN (UNDP), MAES (EU) and UNEP-TEEB-CBD partnerships. In the business world, the Natural Capital Coalition, Conservation International, the U.S. National Oceanic and Atmospheric Administration (NOAA), the Institute of Chartered Accountants in England and Wales and others brought together 60 leading ocean-related organisations in 2017 to ignite the creation of the Natural Capital Protocol for the Ocean[323] to supplement the recognised Natural Capital Protocol[324].

Other natural capital valuation methods are already changing policy and investment decisions[325] (most advanced are perhaps those in China and the United Kingdom, but also other countries are taking up this information and transforming policy and investment, e.g. Belize[326]). These initiatives didn't start in countries' statistical offices but instead were initiated in sector-related ministries (e.g. fisheries, tourism, environment) and in finance ministries.

The digital revolution provides a major boost for ocean national accounting[327]. Online, digital dashboarding makes it possible to drill down quickly to specific indicators of interest in policy analysis and evaluation. The future has begun: an ocean proto-account for Norway can be displayed as an interactive dashboard

Figure 1.11. Example of a Live Interactive Digital Dashboard for Ocean Accounting: Norway Ocean Economy Dashboard



Note: See the live dashboard at https://environment.yale.edu/data-science/norwegian-ocean-economy-dashboard.
Source: Fenichel, E.P., B. Milligan, I. Porras et al. 2020. "National Accounting for the Ocean and Ocean Economy." Washington, DC: World Resources Institute. https://www.oceanpanel.org/blue-papers/national-accounting-ocean-and-ocean-economy.

(Figure 1.11), and the United States hosts an interactive ocean proto-account[328].

A user of the Norway dashboard can define the ocean economy through any combination of six sectors and explore how these interact along various indicators of production, value created, capital used and the like. Although data holes remain (most fundamentally, Norway does not yet include monetisation of its natural capital stocks), the dashboard radically expands the breadth of questions that can be asked and answered[329].

This chapter makes clear that a healthy ocean and a subsequent sustainable ocean economy are crucial allies to address some of the most pressing challenges humanity will face in the 21st century, including food security, climate change and social inequalities. Today the ocean's health is under increasing pressure from anthropogenic stressors. If not addressed these could compound with each other with dramatic consequences. A growing number of initiatives, technologies and business solutions are emerging and show that the possible alternative path of a sustainable ocean economy is realistic and feasible. The next chapter offers a vision where these positive developments are generalised and a sustainable ocean economy can emerge that benefits the people, the economy and the planet.

CHAPTER 2

The Possibility of Tomorrow

Introduction

For centuries, the ocean has been viewed as **'too big to fail'**[330]. However, as shown in Chapter 1, this belief cannot be considered true anymore: overfishing, habitat destruction, climate change and pollution represent a de facto uncontrolled experiment. The size of the challenge could easily lead one to think that the ocean is now **'too big to fix'**[331].

This report offers a more hopeful narrative. Chapter 2 posits that the agendas of ocean and terrestrial resource productivity are no longer separable; neither are the agendas of ocean protection and ocean productivity. As pressure rises on business and political leaders, and as new, sustainable types of ocean ventures demonstrate compelling economics, the tide can turn and the ocean as a source of sustainable prosperity can become **'too important to ignore'**[332].

Chapter 2 of this report invites the reader to take a journey towards an alternative tomorrow, where a set of sound early decisions launches the productive disruptions, pioneers and dynamics that lead to a sustainable ocean economy over the coming decades. This chapter paints a 'vision' of what a sustainable ocean economy could look like and the benefits it could generate. This vision is anchored in science and is feasible if the right decisions are made and several systemic barriers are removed (analysed in depth in Chapter 3, Section 3.1).

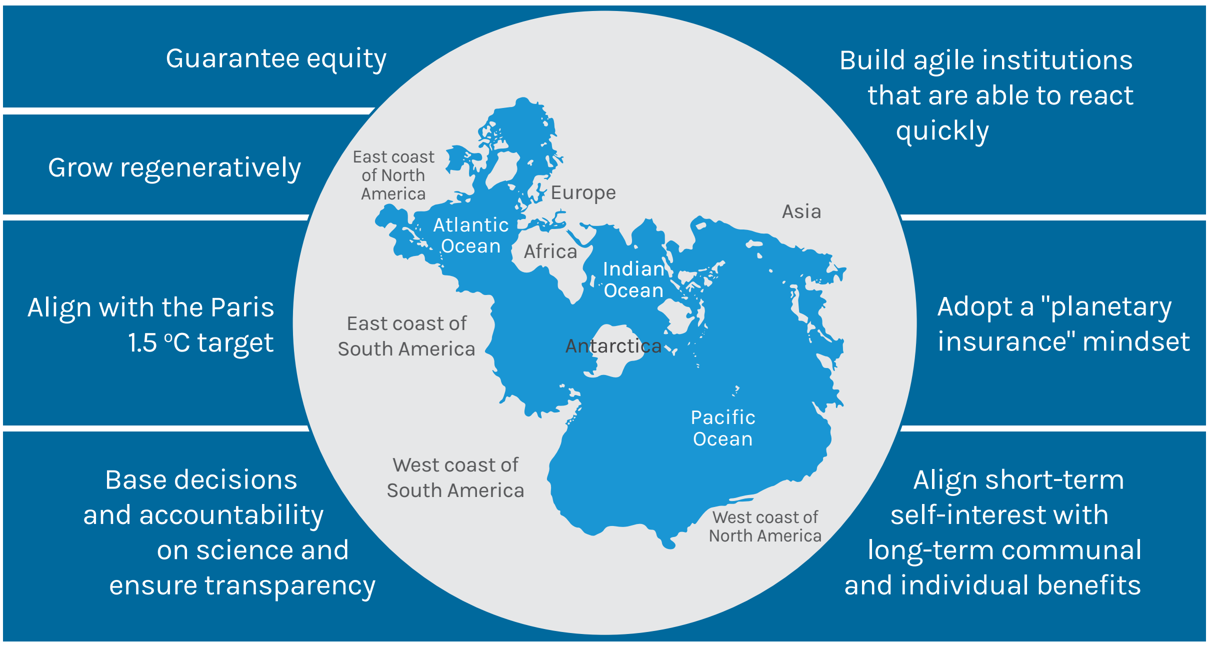
This chapter starts by introducing seven fundamental design principles, suggested as a guiding 'Southern Cross' or 'North Star' (Section 2.1) to scale up the promising trends presented in Chapter 1. It then lays out a vision where five fundamental transformations enable the development of truly sustainable ocean sectors (Section 2.2). Finally, it presents evidence that such a vision can deliver a 'triple benefit' of effective protection, sustainable production and equitable prosperity (Section 2.3).

2.1. Defining a Compass Direction: Principles for a Sustainable Ocean Economy

Seven fundamental design principles are introduced below to help decision-making and prioritisation towards a sustainable ocean economy. Every measure, transformation and example in this chapter is based on these seven fundamental design principles (Figure 2.1).

Guarantee equity. The ocean, as 'the common heritage of humankind', needs to benefit all of humanity. Avoiding coastal food and energy insecurity, labour exploitation and gender discrimination should be given the highest priority and form the bedrock of decision-making related to the ocean economy. This includes respecting relevant international agreements like the SDGs, the UN Declaration on the Rights of Indigenous Peoples and the UN Declaration of Human Rights[333].

Figure 2.1. Principles for a Sustainable Ocean Economy



Source: Authors.

Align with the Paris 1.5°C target. The 2019 UN emission gap report states that the world is currently on course for 3.2°C global warming over pre-industrial levels[334]—presenting a stark contrast to the 1.5°C limit now commonly recognised as critical for ocean health. Establishing a regenerative ocean economy, focused on restored and protected 'blue sinks' (e.g. mangroves, sea grass, saltmarshes) and zero- or low-carbon production of food, energy and transportation, is essential to that goal.

Base decisions and accountability on science and ensure transparency. The age of the unfathomable, inexhaustible ocean is over. Future management must rely on a clear-eyed view of the impacts of climate change, the ocean's resource dynamics, its natural cycles of decline and regeneration and the resilience and vulnerability built into its infinitely complex biological systems. This requires the full and creative use of the data revolution for ocean purposes, the full appreciation and use of scientifically accurate local and Indigenous knowledge, and the commitment of management institutions to follow the advice of scientists.

Grow regeneratively. The ocean economy, at every relevant scale, needs to cumulatively regenerate the ocean's vitality, diversity, and resilience. A sustainable ocean economy needs to ensure that marine economic activities are at least carbon-neutral and support the ocean's biodiversity. Not every project can be carbon-negative or rebuild biodiversity—but projects must be linked such that they bend the arc towards greater ocean health.

Build agile institutions that are able to react quickly. In an increasingly fast and unpredictable world where 'governance failure is routine'[335] and crises like COVID-19 could become more frequent, institutions need to optimize themselves based on the principle of agility and ability to react quickly, while making decisions in an inclusive 'top-down, bottom-up manner'. This move towards shorter reaction times would allow governments, community networks and supra-national interests to adapt quickly to rapidly changing climatic and sociological conditions.

Align short-term self-interest with long-term communal and individual benefits. Current misplaced incentives (economic incentives and behavioural norms) that drive destructive outcomes need to be reconfigured towards a new set of incentives aligned with the other six principles and the vision of a sustainable ocean economy.

Adopt a 'planetary insurance' mindset. The ocean is becoming more unpredictable—the degradation of its health and ecosystem services is accelerating and is non-linear. Setting aside large areas of fully intact and comprehensive ecosystems and habitats is an essential insurance mechanism. The science is clear: large, properly designed protected areas increase the ocean's resilience to a variety of stressors, including warming and acidification. Similarly, the level of uncertainty at play does not allow for uncontrolled experiments and should encourage the following of a stricter, precautionary approach, whether in the exploration of new commercial species or the exploitation of known stocks and new resources like seabed minerals and metals.

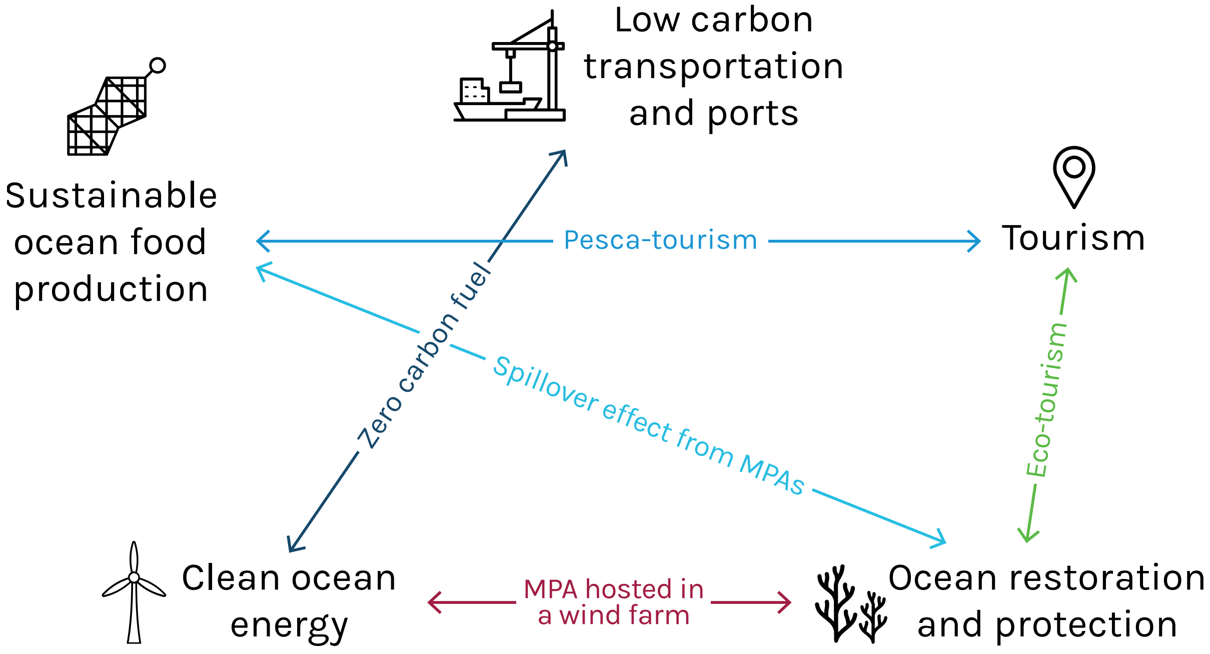
Taking these general principles to their logical conclusion, a potential future emerges that diverges from the dystopian future evoked in Chapter 1.

2.2. A New Picture Is Emerging: The 2050 Sustainable Ocean Economy

It is impossible to predict precisely any version of the 2050 ocean economy—but it is possible to describe an optimistic scenario that combines the main linked components of a sustainable ocean economy (Figure 2.2).

In this sustainable 2050 scenario, a new network emerges of interest groups including fishers, ocean farmers, scientists, civil society, local communities, as well as key energy, shipping and tourism players. This network is economically empowered and culturally deeply vested in ocean health and the sustainable ocean economy principles stated above. The groups of which it is composed create significant societal and economic values by linking offshore wind farms, mariculture, zero-carbon shipping, fuel production and tourism with unprecedented production efficiencies (see Figure 2.2). Carefully situated non-fed and multi-trophic, zero-feed mariculture produces food for millions of coastal inhabitants. Large fully protected marine areas and MPA networks preserve intact ecosystems. Other effective area-based conservation measures and lightly protected MPAs accommodate some sectoral uses of ocean spaces that are compatible with some conservation goals. Large-scale restoration projects (e.g. mangroves, sea grass) are now financed by carbon mitigation fees and offset mitigation arrangements. Wild-caught fisheries implement climate-smart, ecosystem-based fisheries management. Collectively, this new cohort of ocean interest groups, of which youth and women are integral parts, works powerfully within the political economy to advocate for an equitably used ocean, free of pollution and over-exploitation, and with large fully protected areas to ensure ocean health and guard against unexpected changes.

Figure 2.2. The New Contours of a Sustainable Ocean Economy



Source: Authors.

Ocean-user interest groups have championed the importance of healthy ocean ecosystems, kick-starting an increased global understanding of the immense potential of a sustainably managed ocean economy. The spatial complexities of implementing linked and complementary ocean uses have encouraged more systematic ocean planning. Access rights for specific ocean resources have been clarified. Legal and political actions have been taken against land-based polluters. New finance and transaction recording (ledger) technologies have opened global markets for small artisanal producers while ensuring traceability and fair redistribution of the value created. Knowledge commons are allowing transparent sharing of data, assessments and lessons of what is working and what is not, leading to far more agile responses by communities, businesses and nations.

The political realm has responded to the new economic realities. Operating standards and permitting procedures have been clarified and standardised. Net margins of new and innovative ocean businesses are now supported through appropriate risk-reduction measures. Regulatory pressure on land-based polluters has increased. Access laws have been reformed to better balance the goals and needs of multiple stakeholder groups, including commercial and subsistence users. Labour laws have been strengthened, setting international standards to eradicate human rights abuses, and these laws are enforced.

Coastal communities, especially in the tropical realm, have reasserted their traditional use rights and are empowered to regulate access to local fisheries and ocean resources. Secure in their rights of access, they have the luxury of planning for the long term, and they have switched to sustainable stewardship practices. Women-owned cooperatives running near-shore mariculture operations, processing facilities and logistics have become the norm.

In this scenario, this 2050 state did not appear by magic. It was made possible by deliberate political decisions made in the early 2020s and dynamic changes continuing over 30 years to overcome a series of well-established barriers and habits. In this scenario, from 2020 onwards several countries shifted their focus to sustainable ocean management, clearly defined what they wanted to achieve and decided to manage sustainably 100 percent of their areas under national jurisdiction.

To learn and demonstrate feasibility at scale, these countries set up ‘sustainable ocean economic zones’ (SOEZs). These zones promoted ‘projects of choice’ (in line with the seven principles introduced in Section 2.1) with attractive logistical, financial and regulatory benefits. Projects integrated multiple and symbiotic sectors (e.g. energy, food, tourism); provided for well-designed marine protection and restoration areas; and prioritised ocean health, food security and labour protection. A network of scientists, technologists, investors, sustainable businesses, regulators, local communities and government officials collaborated to design these zones, and they defined uses, standards, finance instruments, and conservation and regeneration requirements.

International negotiations on harmful subsidies, illegal fishing, high seas management, Arctic protection and seabed mining came to a productive conclusion. New visions of a stable, zero-waste and regenerative ocean economy moved into the industrial mainstream.

These decisions, directly informed by properly funded science, triggered a chain of transformative events:

- **Ecosystem-based, inclusive spatial planning became the norm**. Careful science-based planning was required to make these spatially and operationally complex projects a reality (see discussion of marine spatial planning in Chapter 3). Siting decisions had to be formalised, access rights legalities had to be codified and potential use conflicts had to be eliminated through careful apportionment. Conservation offsets (fully protected MPAs, coastal restoration projects, buffer zones) had to be clearly defined and gazetted. Over time, ocean planning became an institutionally well-engrained habit, informed by excellent knowledge of the complex ocean ecosystems and the ability to monitor and adapt management to changing environments, driven by economic utility and managed inclusively with all stakeholders.
- **Polluters paid.** The initial projects, and those following in their footsteps, created a strong community of shared economic interests. As pollution from industrial and agricultural sources began to directly affect sustainable ocean economy success, ocean users and land-based communities came together to find solutions to stop leakage of pollution into the ocean. In many countries, courts and agencies found in favour of the ocean interests and reforms on land leaned towards more circular and regenerative practices. At the same time, increased ocean food production forced new food safety standards, covering pollutants such as plastics and mercury.
- **Automation and the data revolution hit the ocean.** As ocean economies became more sophisticated, advanced remote-sensing technologies became indispensable for delineation and enforcement. Distributed ledger and registration technologies (e.g. blockchain[336]) were used to track the differentiated traits of ocean economy products and (ecosystem) services all the way across the value chain to the consumer, responding to stringent sustainability demands from consumers. The demand pressure from major new maricultural development sped up the development of new sources of feed supply. At the same time, information-sharing went both ways—local outcomes, yields, business results, assessments and the like became readily available to investors and policymakers.
- **Investors woke up.** As the economic viability of a sustainable approach to the ocean economy emerged more clearly, investment volumes naturally increased. Over time, financial markets became more sensitive to the risks resulting from competitive distortions (e.g. subsidies of fishery capacity or fossil fuel electricity) and declining ocean productivity (e.g. pollution and/or habitat degradation). At the same time, financial technologies allowed small-scale ocean players to access global markets and strengthen their voice.
- **National accounting changed.** Nations started to make informed decisions based on a full range of metrics covering production, natural capital and human well-being—potentially through official 'national ocean accounts'. The changing nature of the ocean economy was increasingly and positively reflected in such national accounts and eventually began to shape public investments and policies in the ocean realm.

With these trends arcing towards greater balance and efficiency of ocean use over time, the sustainable ocean economy began to thrive, driven mainly by the linked contributions of five economic sectors (see Figure 2.2 and Box 2.1). The paragraphs below describe the dynamics that led to this 2050 vision.

A. Sustainable ocean food production

Multi-/low-trophic mariculture. Mariculture quickly became popular and successful. With a major concentration on low-trophic-level species (seaweed, bivalves, molluscs), it increased the level of local biomass, created new habitats, created new jobs and local income, and provided an alternative to land-based, carbon-intensive meat production, as well as a source of key nutrients like omega-3 fatty acids and iodine. Higher-trophic-level finfish mariculture shed its dependence on fish-derived feeds and adopted strict operating standards addressing disease control, local pollution and escapes. In some cases, low- and higher-trophic production combined into 'integrated (or co-located) multi-trophic farms' with fed (salmon, seabass, grouper, etc.) and unfed species (e.g. bivalves, seaweed) growing together in a symbiotic and low-waste ecosystem. Where relevant, mariculture operations co-located with offshore wind farms, which provided a low-cost and reliable source of electricity for the farm and clean fuel for ship traffic. Strict labour standards were adopted for mariculture operations, while profits and operating risks became evenly spread along the mariculture supply chain. Expansion of mariculture was achieved in a harmonious way that respects Indigenous rights to healthy ocean resources.

Wild-caught fisheries. Fishing fleets (commercial and artisanal) became profitable and stable because fishers' economic and conservation incentives were aligned, wild fish stocks were restored (especially predators), protected against poachers and allocated fairly to fleets and communities to be fished at optimal capacity. Sustainably fished stocks proved more resilient to climate shocks and provided increasingly predictable returns to appropriately sized fleets. International collaboration and strong local enforcement massively reduced IUU fishing, corruption and forced labour on fishing boats. With access rights to fish stocks more firmly defined and enforced, fishing fleets increasingly adopted sustainable yield standards as the most long-term profitable model of fishing. Fuelled by increasing demand and leadership from seafood incumbents, traceability 'from ocean to plate' in the fish supply chain became the norm and supported generalisation of best practices. Perhaps most important, as communities gained more control over local ocean access, benefits became more equitably shared through sustainably financed mechanisms and the food security needs of coastal inhabitants became paramount.

B. Clean ocean energy

The offshore wind sector continued its exponential growth and replaced fossil fuels as the main source of power from the ocean. Intermittency issues were addressed by a new grid and storage infrastructure. Offshore wind farms increasingly provided energy to other offshore uses (e.g. mariculture, shipping) and anchored and delineated large-scale MPAs. In many cases, they emerged as the natural 'centre' of many ocean economic zones.

C. Low-carbon transportation and ports

Shipping continued to move around 90 percent of globally traded goods but accelerated decisively towards zero emissions. A combination of efficiency measures, together with the introduction of new fuels (such as green ammonia or hydrogen), led to a net-zero global shipping fleet. Offshore wind farms provided the energy to generate ammonia or hydrogen, transferred to ships either locally through floating platforms or through ports. Uncontrolled ballast discharges became a thing of the past, and transport efficiencies were boosted through increased automation and revolutionised cargo-tracking systems. Ports became carbon-neutral, eliminated air pollution, implemented labour laws and synchronised their activities with the marine ecosystem they were situated in (adapting shipping lanes to avoid whale strikes, smart dredging, etc.).

D. Ocean restoration and protection

Ocean restoration and protection were largely driven and financed by the pragmatic agendas of carbon mitigation and sequestration, fishery productivity, coastal protection and ocean tourism. Carbon mitigation funds underwrote sea grass and mangrove restoration as highly efficient carbon sequestration projects. Cities and coastal industries underwrote wetland and marsh restoration as the most effective measure exposure to storms and tides. Networks of fully protected and enforced MPAs became commonplace in integrated fishery management and protection of carbon storage plans, often co-located with offshore wind and food production facilities. Ecotourism facilities routinely took advantage of the rich underwater environment of fully protected MPAs.

E. Tourism

Sustainable tourism showed off the beauty of a healthy ocean and created a broad set of ocean defenders, all the while celebrating rather than destroying habitats and diversity. The industry continued to grow, providing enjoyment and livelihoods for millions of people. This growth was based on sustainable tourism growth plans, which countries developed and implemented in the early 2020s. These plans, written in conformity with the sustainable tourism principles of the UN World Tourism Organization, allowed the industry to grow with minimal environmental (no virgin coastal land conversion, carbon-neutral cruise ships, no effluent discard, limitation of visitors to delicate ecosystems) and social impact (no over-tourism). Payment for ecosystem services got mainstreamed through tourism taxes. Through the adoption of these ecosystem fees, coastal tourism accrued benefits to local communities and financed the restoration and maintenance of the coastal and marine ecosystems it relies on.

Other sectors

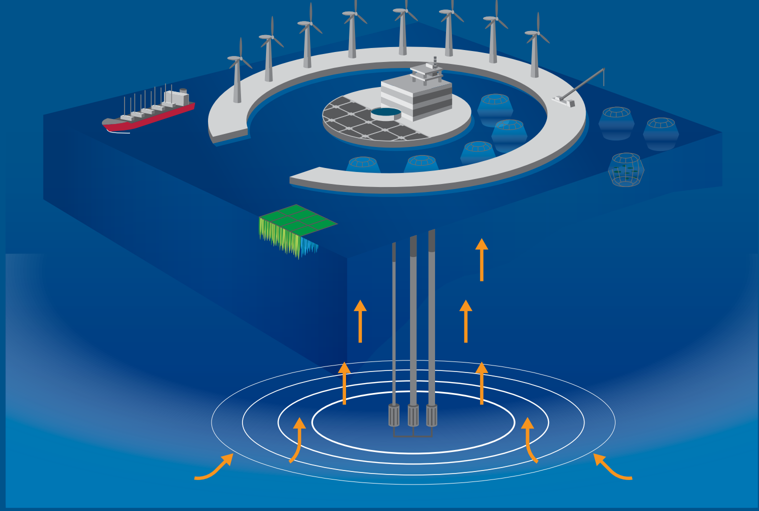
For different reasons, several ocean-related economic sectors are not included or detailed in this report's 2050 scenario of a sustainable ocean economy: industries like maritime engineering and equipment are assumed to follow the development of the above-mentioned

Box 2.1. Concepts of Ocean Multi-use and Sector Coupling

Marine spatial planning is a proven and crucial tool to manage conflicts between ocean users and advance towards more sustainable uses of the ocean[a]. However, the development of sustainable ocean industries remains limited if they are considered as individual and separate activities, ignoring potential synergies[b]: spatial efficiency, circular models (e.g. waste from one as input to another), shared costs and so on. Consequently, there has been a growing interest in the development of a sustainable 'ocean multi-use' concept that fosters synergies among ocean sectors (sector-coupling).

This concept, at the heart of the 2050 sustainable vision described in this section, has been defined by a recent paper as follows[c]: 'Ocean multi-use is the joint use of resources in close geographic proximity by either a single user or multiple users. It is an umbrella term that covers a multitude of use combinations in the marine realm and represents a radical change from the concept of exclusive resource rights to the inclusive sharing of resources and space by one or more users'.

The EU Commission has been pioneering this concept by funding research and a series of large-scale collaborative projects over the past 10 years, including TROPOS, MERMAID, H_2Ocean, Multi-use in European Seas (MUSES) and Marine Investment for a Blue Economy (MARIBE). These concepts are today mostly at the (advanced) blueprint stage, but new three-year funding has just been confirmed to test pilots until 2023 (project UNITED)[d].



Adapted from Fernando Montecruz for the TROPOS Project, 2013.

[a] *"DIRECTIVE 2014/89/EU of the European Parliament and of the Council of 23 July 2014 Establishing a Framework for Maritime Spatial Planning." 2014. Brussels: Official Journal of the European Union. doi:* 10.1007/978-1-137-54482-7_33.

[b] *Lukic, I., A. Schultz-Zehden, J. Onwona Ansong, S. Altvater, J. Przedrzymirska, M. Lazić, J. Zaucha et al. 2018. "MUSES (Multi-use in European Seas) Project v. 3.0 MUSES Deliverable 4.2.1 Multi-use Analysis." Edinburgh, UK: MUSES Project. https://pdfs.semanticscholar.org/9796/7530c175e9e1bcf6f7f7087991ca60613575.pdf.*

[c] *Schupp, M.F., M. Bocci, D. Depellegrin, A. Kafas, Z. Kyriazi, I. Lukic, A. Schultz-Zehden et al. 2019. "Toward a Common Understanding of Ocean Multi-use." Frontiers in Marine Science 6. doi:* 10.3389/fmars.2019.00165.

[d] *Community Research and Development Information Service. n.d. "Multi-use Offshore Platforms Demonstrators for Boosting Cost-Effective and Eco-friendly Production in Sustainable Marine Activities." https://cordis.europa.eu/project/id/862915. Accessed 17 August 2020.*

[e] *Lu, S.-Y., J.C.S. Yu, J. Wesnigk, E. Delory, E. Quevedo, J. Hernández, O. Llinás et al. 2014. "Environmental Aspects of Designing Multi-purpose Offshore Platforms in the Scope of the FP7 TROPOS Project." In OCEANS 2014: TAIPEI, 1–8. doi:* 10.1109/OCEANS-TAIPEI.2014.6964306.

sectors. Other sectors not included or detailed in this report's sustainable ocean economy scenario include the following:

Marine biotech. The scale of genomic diversity in the ocean is difficult to comprehend and poorly understood. Over 33,000 marine natural products—naturally occurring molecules produced by marine organisms—have been discovered[337], many with remarkable levels of biological activity, and probably only representing a very small subset of the total ocean genomic diversity. The revolution in gene sequencing and bioinformatics has allowed for considerable innovation in ocean protection and production. Sequencing costs have declined 1,000-fold over the past decade, and 100,000-fold since the beginning of the millennium[338], allowing millions of DNA fragments to be sequenced simultaneously and inexpensively, creating an intensely data-rich field. However, the sector is still in its infancy. Since its future is hard to predict, the marine biotech sector has been excluded from the future vision scenario.

Deep-seabed mining. As an emerging industry in the ocean, deep-seabed mining is often considered as an example of the 'new blue economy'. It fits the blue economy definition of the EU Commission (i.e. all economic activities related to the ocean), but it remains to be seen if it will meet the World Bank definition (i.e. sustainable use of ocean resources for economic growth, improved livelihoods and jobs while preserving the health of ocean ecosystems). Indeed, recent science clearly states that greater knowledge of the environmental impacts, as well as the ability to mitigate these to acceptable levels, is required before we can be confident that engaging in industrial-scale deep-seabed mining would bring a global net benefit[339].

The proponents of deep-sea mining typically claim that the extraordinary richness of the underwater ores would result in far lower environmental impacts than mining on land, making deep-seabed mining the best option to supply a growing global demand for cobalt, copper, nickel, silver, lithium and rare earth elements, driven by the green transition of the economy (e.g. solar photovoltaics, wind turbines, electric cars)[340]. Mining deep-sea polymetallic nodules is indeed calculated to release less CO_2 per kilogram than mining on land[341]. Mining interests such as Deep Green and Global Sea Mineral Resources (GSR) consider deep-sea minerals to be essential to combating climate change[342]. If profitable, deep-sea mining could also provide an economic development opportunity for many countries.

However, these claims need to be balanced against the risks. Current scientific understanding of deep-sea ecosystems—the range of species, their movements, ecological connectivity and susceptibility to mining stress—is still in its infancy. Deep-sea communities are known to recover from disturbance very slowly, if at all[343]. The impact of deep-seabed mining on marine life—with its associated toxicity, dredging, noise and intense disturbance of the seafloor—is likely immense given the great longevity (thousands of years) and slow growth of many deep sea animals[344]. The profitability of national mining operations, without governmental support or comparably low taxes, remains questionable. If the operations are profitable, it will also raise questions about the equitable sharing of profits derived from a resource taken out of humanity's common heritage[345]. Finally, deep-sea mining may conflict with other marine uses, with complex legal and political ramifications in the international waters of the open ocean[346].

Until the need for, and potential consequences of, deep-sea mining are better understood, the concept is conceptually difficult to align with the definition of a sustainable ocean economy and raises various environmental, legal and governance challenges, as well as possible conflicts with the UN Sustainable Development Goals[347]. It is thus not discussed further in this report.

Oil and gas. 'The whale in the room': how should the oil and gas sector be included in a report on a sustainable ocean economy? On the one hand, it is the largest sector of the current ocean economy by far, accounting for 34 percent of its GVA, according to the OECD[348]. Massive capital investments are locked into extraction facilities, many with decades to go in their useful lives. Equally massive investments are planned soon: in the next 20 years, projected offshore crude oil output will grow from 30 percent to 50 percent of total global production, and almost half of remaining technically recoverable oil reserves are offshore[349]. Within the offshore realm, the share of deep water (125—1,500 metres) and ultra-deep water (>1,500 metres) production is projected to increase to 50 percent by 2020. More than half of major oil and gas discoveries since 2000 have been in the deep ocean[350].

At the same time, exploitation of the technically feasible offshore oil deposits would exceed the remaining CO_2 budget commensurate with the 1.5°C or even 2°C future, which is crucial for ocean stability and viability[351]. In addition, the new frontiers (the deep ocean and the Arctic) are technically challenging, ecologically risky and often occur in remote areas, far from ports and infrastructure. The Deepwater Horizon disaster is a vivid example of the potential scale of oil spills, and the U.S. Bureau of Ocean Energy Management estimates a 75 percent chance of one or more large spills over the lifetime of development and production in Alaska's Chukchi Sea.

Continued or increased offshore oil and gas exploration is conceptually difficult to align with the definition of a sustainable ocean economy, and it is thus not discussed in this report.

The decommissioning of existing offshore platforms may offer interesting possibilities. Decommissioning expenses are estimated to increase from $2.4 billion in 2015 to $13 billion per year in 2040. The cost of removal is often tax-supported and could be reduced with potential re-use applications[352]. For example, North Sea countries are gradually decommissioning about 600 oil and gas installations[353] at the same time as they are installing massive new offshore wind capacity. Decommissioned oil and gas platforms could conceivably be used to convert and store offshore wind energy (e.g. in the form of hydrogen or ammonia fuels) in ways that eliminate costly hook-ups with onshore grids[354]. Other conversions, such as 'rigs to reefs' conversions or repurposing as tourist centres, are already used today[355].

The development of offshore wind capacity is extensively discussed in this report. There are very interesting opportunities for using renewable offshore energy as the focal point for other sustainable ocean ventures, ranging from mariculture to shipping fuel generation, tourism and protected areas. The widespread and essential development of ocean renewable energy will require wide-ranging reforms of ocean planning and access control systems, all of which are also discussed in this report.

2.3. The Big Reconciliation: Protect Effectively, Produce Sustainably and Prosper Equitably

This section demonstrates that a sustainable 2050 ocean economy could simultaneously deliver in three ways: (1) it could effectively **protect**, reducing greenhouse gas emissions while safeguarding biodiversity and associated ecosystem services; (2) it could sustainably **produce**, helping sustainably power and feed a planet of 10 billion people; and (3) it could enable humanity to equitably **prosper**, creating better, more equitable jobs and redistribution of benefits, and supporting economic growth, household income and well-being, while prioritising access, equitable decision-making and benefits that support equity and reduce unequal impacts and harm on the most vulnerable (Figure 2.3).

Protect effectively

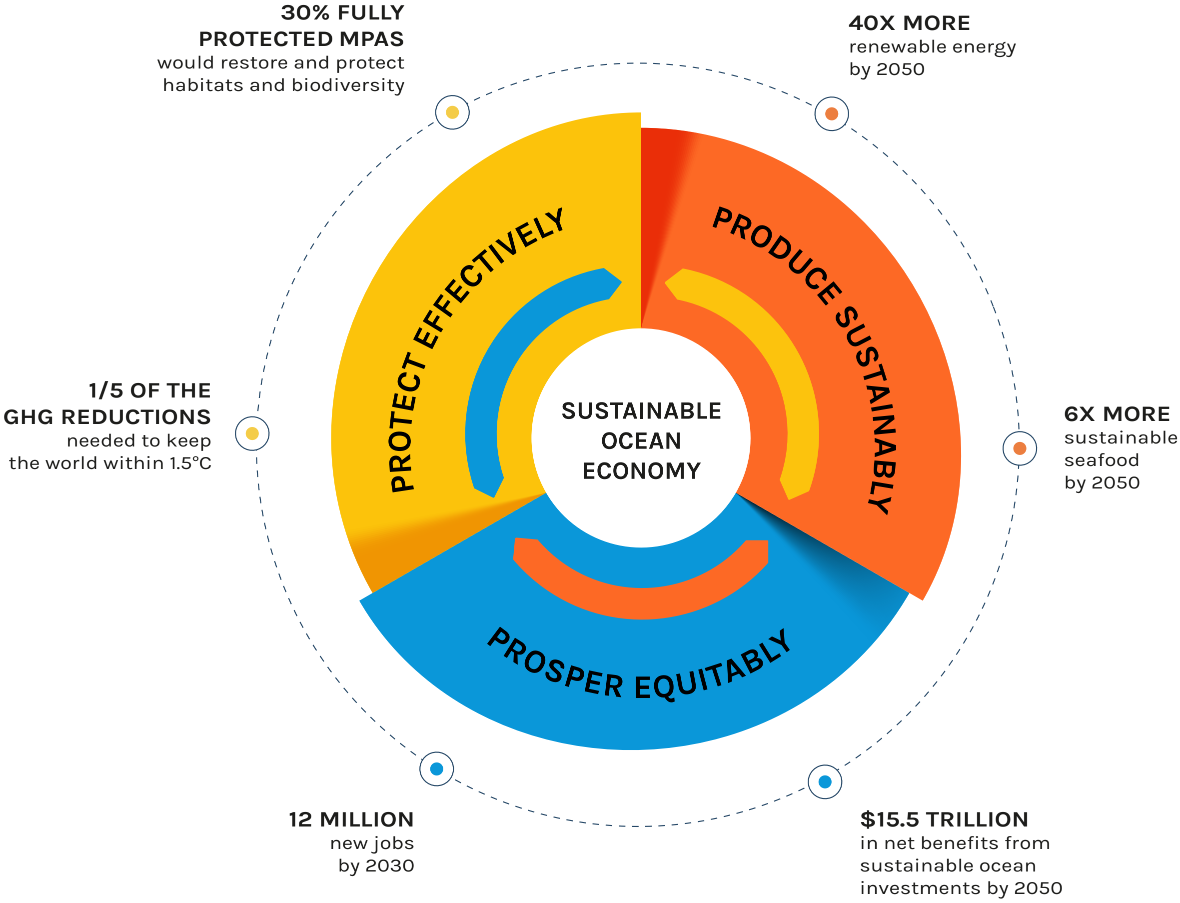
A sustainable ocean economy can help keep the climate within the Paris Agreement boundaries and protect and regenerate the ocean's biodiversity and associated ecosystem services.

Climate. Absorbing a third of the planet's CO_2 emissions and about 93 percent of the world's human-induced additional heat[356], the ocean is already shouldering a significant part of regulating Earth's climate. In the process, it is becoming warmer, more acidic and higher. Nonetheless, the ocean economy's potential role in active climate mitigation is far from realised today. In a sustainable ocean economy, ocean-based renewable energy could play a much more important role than today: shipping would be zero-emission, fisheries and mariculture would be much more energy efficient, coastal ocean assets would be restored and protected, and CO_2 could be stored in the seabed. 'The Ocean as a Solution to Climate Change' (2019) analysed the CO_2 abatement potential from these five areas and concluded that the ocean could contribute up to 21 percent (or 11.8 $GtCO_2e$) of the emission reduction required to achieve a 1.5°C trajectory by 2050[357] (Figure 2.4). In such a vision, the ocean would move away from being solely a climate change victim (warming, acidification, etc.) towards actively participating in the climate change mitigation solution.

A sustainable ocean economy would also help catalyse deep reforms of the land-based plastics value chain. Indeed, a holistic, circular approach to ocean plastics could reduce annual ocean plastic leakage by 80 percent, compared to a BAU scenario where this flow is expected to triple by 2040[358]. Given CO_2 emissions associated with plastics production, use and end of life, this holistic approach has the potential to reduce CO_2e emissions associated with the plastics value chain by 25 percent compared to BAU 2040[359]. The plastics value chain would otherwise emit an estimated 4.5 $GtCO_2e$ by 2050—roughly 7 percent of global emissions in a BAU scenario—with the attendant warming and acidification effects on the ocean[360].

Reduced other sources of pollution from land. By drastically limiting leakage into the ocean, the plastics value chain holistic and circular approach would limit the growing pressure on ocean fauna and flora. The same logic could apply with other land-based pollution. Even if the correlation is harder to demonstrate, the sustainable ocean economy agenda could help catalyse broader reforms of the land-based food system, most notably in agriculture. One can expect that agricultural regulations aimed at reducing ocean dead zones could

Figure 2.3. A Sustainable Ocean Economy Can Create a Triple Win for People, Nature and the Economy

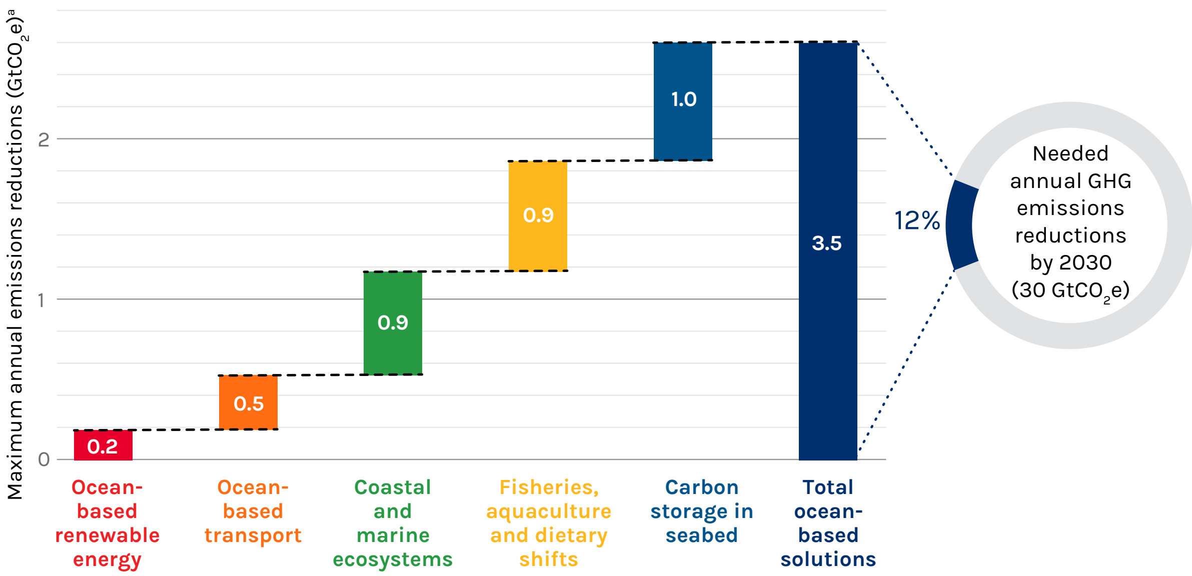


Note: MPAs: Marine protected areas. GHG: Greenhouse gas emissions.
Source: Authors, drawing on the following sources: OECD. 2016. The Ocean Economy in 2030. Directorate for Science, Technology and Innovation Policy Note, April. https://www.oecd.org/futures/Policy-Note-Ocean-Economy.pdf; Konar, M., and H. Ding. 2020. "A Sustainable Ocean Economy for 2050: Approximating Its Benefits and Costs." Washington, DC: World Resources Institute. https://www.oceanpanel.org/Economicanalysis; Costello, C., L. Cao, S. Gelcich et al. 2019. "The Future of Food from the Sea." Washington, DC: World Resources Institute. https://www.oceanpanel.org/blue-papers/future-food-sea; Hoegh-Guldberg, O., et al. 2019. "The Ocean as a Solution to Climate Change: Five Opportunities for Action." Washington, DC: World Resources Institute. https://oceanpanel.org/sites/default/files/2019-10/HLP_Report_Ocean_Solution_Climate_Change_final.pdf.

result in farmers adopting precision agriculture practices to avoid runoff. The adoption of precision agriculture, in turn, would have a positive impact on soil health and water quality in rivers and streams.

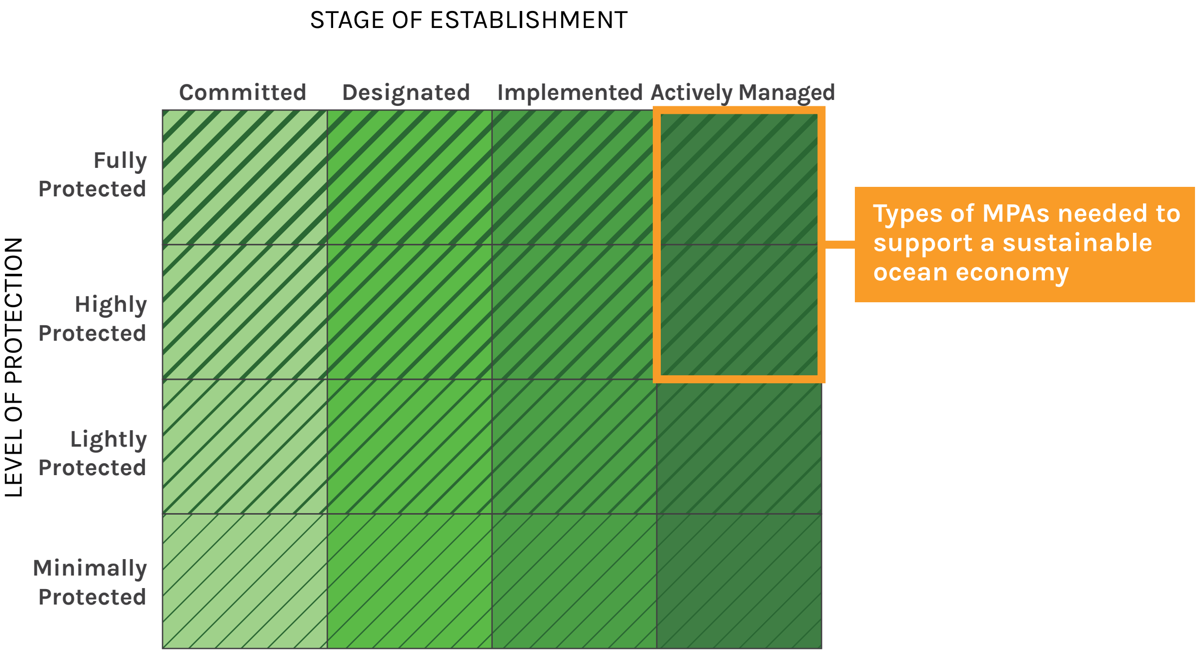
Ocean and coastal ecosystems, biodiversity and biomass. In a 2050 sustainable ocean economy, the economic value of restoration of ocean and coastal natural capital would be recognised and turned into action, with carbon finance and coastal protection funds playing a major role in large-scale restoration projects. Restored and protected natural blue assets would then be able to deliver ecosystem services for coastal populations, especially in ensuring human safety by helping to mitigate the impacts of storms and sea level rise. For instance, healthy coral reefs reduce wave energy by up to 97 percent, protecting up to 100 million coastal inhabitants from storm risks[361]. In addition, a study has found that a '100-meter-wide belt of mangroves can reduce wave heights between 13 and 66%, and up to 100% where mangroves reach 500 meters or more in width'[362]. This study also found that saltmarshes can attenuate up to 50 percent of smaller waves, even with a barrier of just 10 metres[363].

Figure 2.4. Contribution of Five Ocean-Based Climate Action Areas to Mitigating Climate Change in 2030 (Maximum $GtCO_2e$)



Note: [a] To stay under a 1.5°C change relative to pre-industrial levels.
Source: Hoegh-Guldberg, O., et al. 2019. "The Ocean as a Solution to Climate Change: Five Opportunities for Action." Washington, DC: World Resources Institute. https://oceanpanel.org/sites/default/files/2019-10/HLP_Report_Ocean_Solution_Climate_Change_final.pdf.

Figure 2.5. The MPA Guide



Source: Adapted from Oregon State University, IUCN World Commission on Protected Areas, Marine Conservation Institute, National Geographic Society and UNEP World Conservation Monitoring Centre. 2019. "An Introduction to the MPA Guide." https://www.protectedplanet.net/c/mpa-guide.

'Planetary insurance' in the form of MPAs would have been generalised and integrated within the 100 percent managed EEZs and a legal mechanism to create large, fully protected MPAs on the high seas. By restoring biodiversity, these MPAs increase the resilience of the ecosystems, since they provide a protected home for communities that are capable of 'differential response'[364]. These MPAs would be primarily highly or fully protected and actively managed to obtain the greatest conservation outcomes[365]. In visual terms, if plotted on the chart of Figure 2.5, the majority of MPAs in a sustainable ocean scenario would be in the top right-hand corner. Indeed, species richness has been found to be 21 percent higher and biomass up to six times greater within fully protected marine areas (from here on simply called MPAs) compared to the adjacent unprotected areas[366].

In a sustainable ocean economy scenario, the MPA placement would not be chosen randomly but designed according to science-based criteria, local knowledge and in consultation with diverse stakeholders. For instance, scientific analyses can produce scenarios to locate areas that maximise three benefits of MPAs: (1) rebuilding and safeguarding biodiversity, (2) mitigating climate change (by avoiding emissions from the disturbance of sediment carbon by bottom trawling and eventually deep-sea mining) and (3) boosting fisheries productivity (by increasing fisheries catches around MPAs through the spillover of fish). The food benefits would only be captured if the MPA strategy has been coupled with the sustainable management of the surrounding fisheries and an inclusive process that actively involves local communities and marginalised groups in the design and establishment of the MPAs.

Produce sustainably

In the sustainable ocean economy scenario adopted in this chapter, effective ocean protection would enable sustainable ocean production. Most notably, the ocean can produce a near unlimited amount of renewable energy and significantly more seafood than today. In this section, an ambitious but realistic production potential is described.

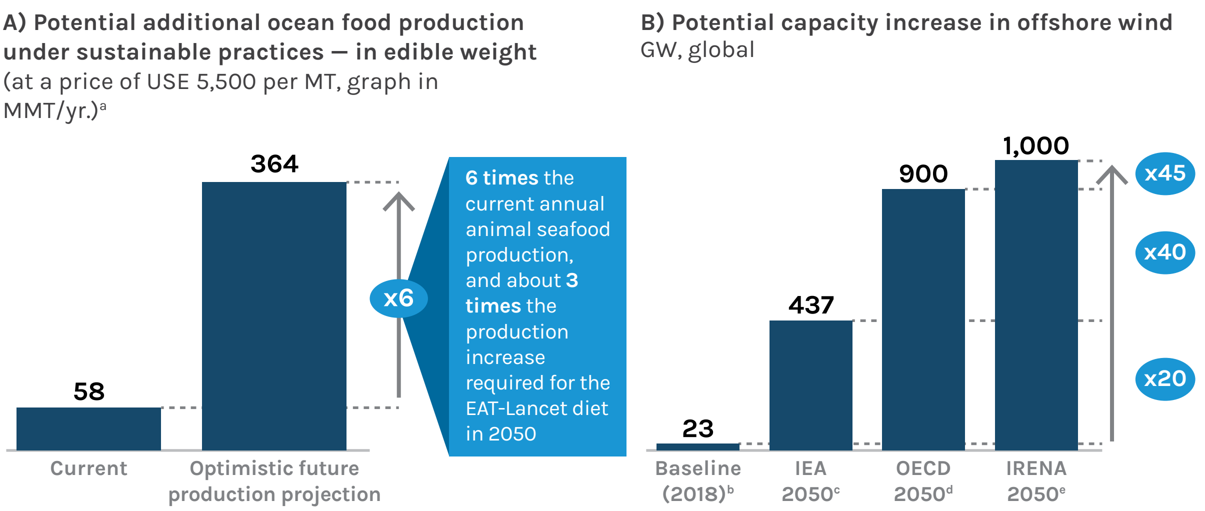
Ocean-based renewable energy. There appear to be no relevant physical limits to ocean-based production of renewable energy. Estimates for total technically feasible global offshore wind power generation potential range from 157,000 terawatt hours per year (TWh/yr.) to 631,000 TWh/yr.[367]—6 to 23 times more than the total global electricity consumption in 2018 (26,700 TWh/yr.)[368]. Europe's offshore wind potential alone (71,845 TWh/yr.) is estimated to be over three times the current global electricity demand[369]. Other forms of ocean-based energy also have a very significant technically feasible potential, such as tidal energy (around 6,200 TWh/yr.)[370], wave energy (between 1,750 and 5,550 TWh/yr.)[371], ocean thermal energy conversion (technical potential uncertain)[372] and salinity gradient energy (1,650 TWh/yr.)[373]. However, their cost is far from competitive today. By most realistic estimates, offshore wind will remain the most competitive offshore energy source, although the pace of development will remain far below theoretically feasible levels over the coming decades.

The International Energy Agency estimates that 570 GW of offshore wind could be installed by 2040[374]. An OECD scenario projects 900 GW by 2050[375] and the International Renewable Energy Agency (IRENA) REmap Scenario projects 1,000 GW of installed offshore wind by 2050[376]. This suggests that even the upper range of the scenarios used in the Ocean Climate Special Report[377] may turn out to be conservative.

Sustainable seafood. The ocean could in theory sustainably produce six times more food than today under an optimistic scenario[378], thereby playing a significantly greater role in ensuring the food security of a planet with 10 billion people in 2050. It has the potential to do so with a low environmental footprint (e.g. with sustainable fed mariculture and sustainable fisheries) or even in a regenerative way (e.g. with non-fed mariculture). Delivering this potential, however, depends on climate-adaptive, in-depth reforms of wild-catch fisheries, evolution of consumer preferences and significant scaling of (sustainable) mariculture:

- **Wild-catch fisheries.** Currently, most fishing is not economically or ecologically optimised. Far too many stocks are pursued by too many boats; far too much seafood value is lost due to poor handling; and far too many non-target species are accidentally caught. If this approach continues, 2050 yield is expected to decrease to about 67 MMT/yr.[379]. However, if all stocks currently exploited were to be fished at maximum sustainable economic yield[380], production could increase to 96 MMT/yr. in 2050: an additional 16 MMT/yr. of seafood compared to today[381]. This represents a 20 percent production gain over today's production levels, and a 40 percent increase over estimated BAU catch. It is important to note that these optimistic gains depend on the deployment of effective, climate-adaptive fishery reforms, strengthened international institutions and cooperation, in combination with scale-up of marine protected areas (see Chapter 3 for more details).

Figure 2.6. Ocean Food and Energy Production Potential Increase under a Sustainable Ocean Economy Scenario



[a] *Costello, C., L. Cao, S. Gelcich et al. 2019. "The Future of Food from the Sea." Washington, DC: World Resources Institute. https://www.oceanpanel.org/blue-papers/future-food-sea.*

[b] *IRENA. 2019. "Future of Wind: Deployment, Investment, Technology, Grid Integration and Socio-economic—Executive Summary." Abu Dhabi: International Renewable Energy Agency. https://irena.org/-/media/Files/IRENA/Agency/Publication/2019/Oct/IRENA_Future_of_wind_2019_summ_EN.PDF.*

[c] *IEA and ETP. 2017. "International Energy Agency, Energy Technology Perspectives 2017." www.iea.org/etp2017.*

[d] *OECD. 2016. The Ocean Economy in 2030. Report. Paris: OECD Publishing. https://www.oecd.org/environment/the-oceaneconomy-in-2030-9789264251724-en.htm.*

[e] *IRENA. 2019. "Future of Wind."*

- **Mariculture.** The production of sustainable fed (finfish) and unfed (bivalve, seaweeds) mariculture is currently at a very small fraction of its biological potential (the theoretical production limit is estimated at 15,000 MMT/yr.—far more than 470 MMT of meat will be required annually in 2050 to feed the projected global population of more than 9.7 billion)[382].
  - Fed mariculture requires external feed (today including fish oil and fish meal) and is currently severely constrained by the price and availability of feed. Under optimistic projections assuming a 95 percent reduction of fish meal and fish oil content in mariculture feed, current production could be multiplied 10-fold[383]. However, the siting and operations of monocultural, high-trophic finfish farms, especially in pristine areas, is often highly controversial. A re-imagined approach to finfish farming, focused on local food security concerns, multi- and low-trophic species, new disease control and containment technologies, and avoidance of pristine areas, will be essential to capture the biological potential in a sustainable way.
  - Non-fed mariculture is ecologically largely benign and offers great potential. Bivalve mariculture (e.g. mussels, oysters), for example, could theoretically be increased more than 30-fold beyond current production to its biological potential of 460 MMT/yr. (bivalves only)[384]. Seaweed, with a suitable cultivation area of 48 million km^2, has the potential to play a substantially larger role in supplying humanity with food and land animals and fish with feed. Seaweed also constitutes a very promising low-carbon source for raw materials that can be used in biostimulants (fertilisers), cosmetics, bioplastics, biofuels and other applications. In a sustainable ocean economy, the current economic, technological and regulatory barriers hindering the expansion of non-fed mariculture must be overcome (see Sections 3.1 and 3.2)[385].

With these elements in mind, it is safe to say that reforming wild-caught fisheries and growing sustainable mariculture (especially unfed species) could multiply current ocean food production by up to six times by 2050 (Figure 2.6)[386].

Prosper equitably

This discussion describes prosperity in terms of jobs, economic wealth creation, inclusivity and equity if a sustainable ocean economy vision is realised. Only a small and simple sampling is possible—an exhaustive account of the relative upside of a restored, vibrant and productive ocean would fill libraries.

The future of ocean jobs, in many ways, echoes the general employment trends on land. In the energy sector, job growth is shifting to renewables, with many high-level engineering and support jobs created, especially in the developed world. Rising levels of productivity and automation would shift jobs in shipping, commercial fishing and large-scale mariculture from the front line to expert support (engineering, information technology, data, applied science, infrastructure). Small-scale fisheries would increasingly come under local control, recovering their productivity but imposing limits on fishing effort, enabled by smart policies that ensure secure access.

This report describes potential long-term evolutions of ocean jobs, building on various sources and projections from the pre-COVID period. The COVID-19 pandemic has seriously affected many ocean industries, making these projections and future jobs trajectories highly uncertain. For instance, up to 100 million jobs are today considered at risk in the tourism sector alone[387]. In addition, the crisis affecting ocean-based sectors is disproportionately hitting women and more vulnerable groups (low-skilled workers, small-scale fishers and businesses, Indigenous community members, younger workers, etc.)[388]. Recovery and economic stimulus plans supporting a sustainable ocean economy are expected to help maintain employment in ocean sectors and/or help transition towards the jobs required to develop the sustainable ocean sectors presented in this chapter.

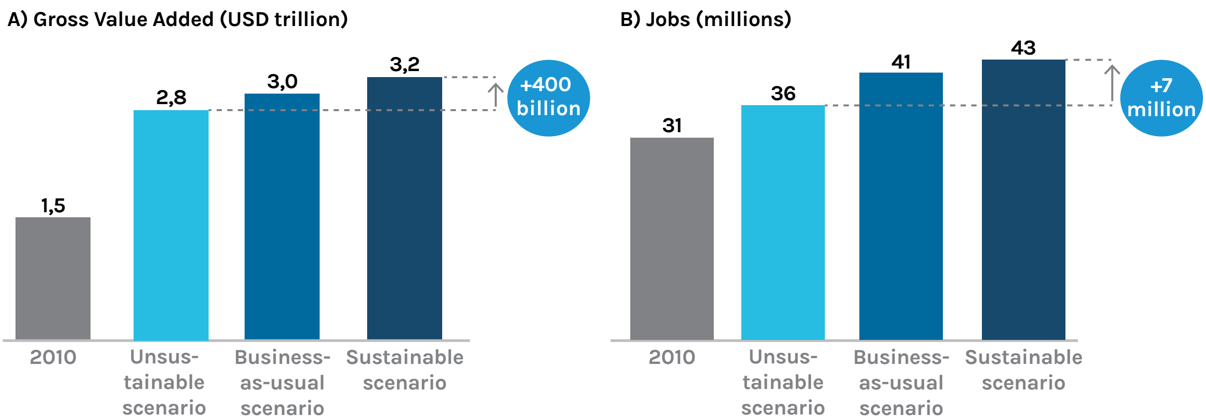
- **Offshore energy.** Offshore energy is growing fast from a small base. Even in a conservative scenario, many jobs could be created: the OECD's BAU scenario (assuming no significant new government incentives) estimates the creation of 440,000 new jobs by 2030 in the offshore wind sector[389]. More assertive energy and industrial strategies could increase this number sharply. In the longer term, renewables are expected to outperform fossil fuel jobs in both relative and absolute numbers. In 2017, the U.S. Bureau of Labour Statistics listed turbine technician as the second-fastest-growing occupation in the United States. With periodic downturns in the offshore oil and gas industries, many oil and gas workers are turning to the wind industry for high-paying jobs. In U.S. coastal regions, 160,000 gross jobs could be supported by the offshore wind industry in construction, installation, operations and maintenance[390].

- **Shipping and ports.** According to the OECD, seaborne cargo volume, driven almost entirely by GDP, will almost double from 11 billion tons in 2015 to 20 billion tons in 2030, which can be expected to significantly increase employment[391]. A more granular view reveals the major trends. A major expansion in ports, driven at least in part by China's massive Maritime Silk Road initiative, can be expected to increase trade. Larger and more automated vessels may slow job growth in shipping and shipbuilding, however (tonnage of ships larger than 7,600 20-foot equivalent units (TEUs) can be expected to increase 6–6.5 times between 2010 and 2030, much faster than for ships under 7,600 TEUs, projected to grow 1.4–2 times)[392].

- **Fishing and mariculture.** Global fishing, at the commercial and artisanal or small scale, operates at significant overcapacity today; there are too many fishers and too many boats. Because of this overcapacity, fish stocks, productivity and yields are depressed, and coastal livelihoods can be threatened. Net job growth is thus not the relevant metric to be applied to fishing—but job security is, alongside food security and productivity. Nevertheless, the reduction of fishing capacity, and the associated stranded assets, may create tensions which must be thoughtfully addressed (through structural adjustments, reskilling, etc.; see discussion in Section 3.1). For industrial capture fisheries, jobs can be expected to decline, as fleets slowly reduce capacity and increase efficiency. Artisanal jobs are much harder to define and track—estimates range from 12 million[393] to 37 million, with an additional 100 million artisanal jobs being dependent on fishing (e.g. fish processors)[394]. Many artisans fish opportunistically for food, rather than as a full-time pursuit. In a sustainable ocean economy, their time on the water will decrease, and yields will increase.

- The OECD projects strong mariculture employment growth to 3.2 million jobs in 2030, up from 2.1 million in 2010 under a BAU scenario. However, much higher job growth is possible if new technology can eliminate current constraints on feed availability and the production of non-fed mariculture is boosted. Buoyed by the growing maricultural capacity and recovering industrial capture yields, jobs from the seafood processing sectors can be expected to grow as well[395].

Figure 2.7. 2010–30 GVA and Job Creation Associated with Different OECD Scenarios



Source: OECD. 2016. The Ocean Economy in 2030. Directorate for Science, Technology and Innovation Policy Note, April. https://www.oecd.org/futures/Policy-Note-Ocean-Economy.pdf.

- **Tourism**. Payment for ecosystem services through tourism fees could be adopted to finance the restoration and maintenance of the natural ecosystems (future) coastal tourism jobs rely on. Pre-COVID, the tourism sector was expected to continue its strong growth, directly accounting for over 8.5 million jobs in 2030 (up from 7 million in 2010)[396]. Post-COVID, the trajectory for the tourism sector is still uncertain.

The economic future. The size of the prize of the transition to a sustainable ocean economy is significant and appears to be limited far more by political and economic constraints than the ocean's productive potential. As for the jobs section, the numbers presented below reflect long-term evolutions and economic gains, building on various sources and projections from the pre-COVID period. Significant economic losses have been experienced by ocean sectors during the COVID-19 pandemic, and there is a high uncertainty as to the pace of recovery and transition towards a sustainable ocean economy for these sectors. For instance, cancellation of shipping is estimated to have caused revenue loss of US$1.9 billion for the carriers in a matter of months[397].

On the conservative side, the OECD predicted in 2016 that economic growth and employment under a sustainable scenario would outpace both an 'unsustainable' and a 'BAU' scenario (see Figure 2.7).

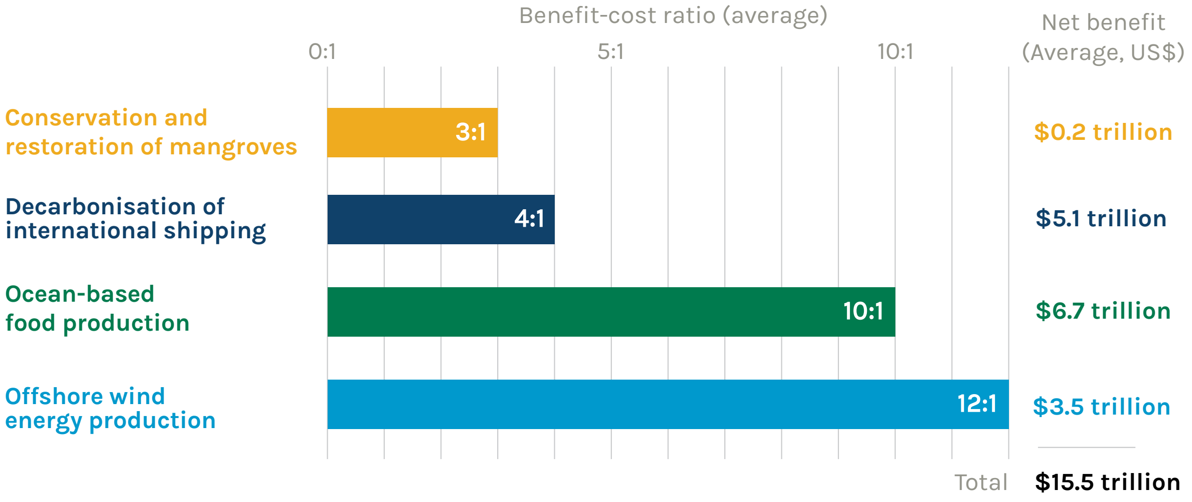
The OECD projections were based on 2010 data points as a baseline. A more recent study commissioned by the Ocean Panel provides a far more optimistic picture, with a net benefit estimated at $15 trillion by 2050 if $2.8 trillion were invested today in four sustainable ocean-based solutions: sustainable ocean food, renewable ocean energy, decarbonisation of international shipping, and conservation and restoration of mangroves[398]. The benefit-cost ratio differs for each of these opportunities, but overall it remains very attractive—see Figure 2.8 below. These numbers are accounted through a holistic view that encompasses benefits of three kinds: economic (e.g. increased profits from higher fisheries productivity), environmental (e.g. avoided damages from coastal flooding) and health (e.g. reduced mortality from improved air quality).

Such an analysis has a number of limitations, as it does not represent the distribution of the benefits (and costs), it puts a monetary value on nonmarket goods with debatable assumptions, and it is obliged to omit certain benefits that are still very hard to monetise (e.g. prevention of the loss of natural habitats from increased ocean acidification). However, it serves as a very useful pointer, emphasising that ocean-based solutions should be considered as high-return investments and essential engines of a post-COVID economic, social and environmental recovery strategy.

Looking at the more detailed assessment of these four ocean-based solutions, this benefit-cost analysis offers conclusions in the following areas[399]:

- Mangrove conservation and restoration**:** Every $1 invested in mangrove conservation and restoration generates an average benefit of $3. Conservation has a far higher return on investment (88-to-1) than restoration (2-to-1), which can mainly be explained by the higher cost of mangrove restoration and the low survival rates following restoration. The total

Figure 2.8. Benefit-Cost Ratios and Net Benefits by 2050 for Four Sustainable Ocean-Based Interventions



Note: Average benefit-cost (B-C) ratios have been rounded to the nearest integer and the net benefits value to the first decimal place. The B-C ratio for mangroves is the combined ratio for both conservation- and restoration-based interventions. The average net benefits represent the average net present value for investments and is calculated over a 30-year horizon (2020–50).

Source: Konar, M., and H. Ding. 2020. "A Sustainable Ocean Economy for 2050: Approximating Its Benefits and Costs." Washington, DC: World Resources Institute. https://www.oceanpanel.org/Economicanalysis.

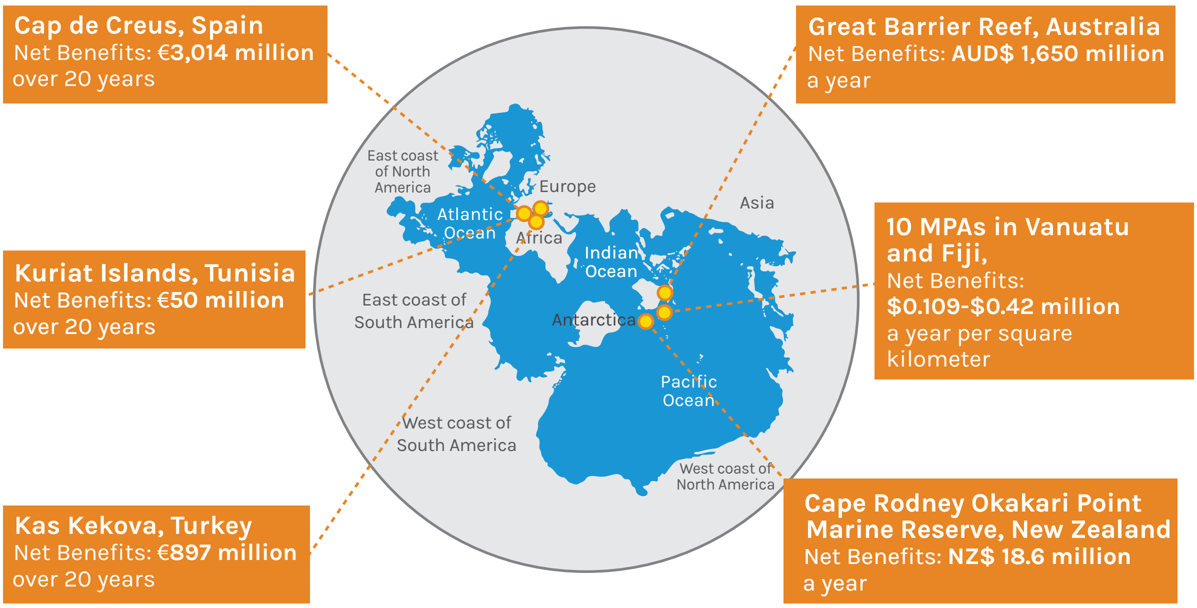
value of net benefits for mangrove restoration over 30 years ($97–$150 billion) is, however, higher than for conservation ($48–$96 billion), as the surface is assumed to be 10 times larger for restoration.

- Offshore wind**:** Every $1 invested in scaling up global offshore wind production generates a benefit estimated at $2–$17, depending on the cost of offshore energy production and transmission and the types of generation that would be displaced. The return on investment will increase as technology and efficiency improvements bring down costs for offshore wind energy generation.
- Green shipping**:** Every $1 invested in decarbonising international shipping and reducing emissions to net zero by 2050 is estimated to generate a return of $2–$5. The analysis assumed that the significant capital expenditure to switch to zero-carbon emissions will happen after 2030, and limiting the analysis to 2050 captures only a portion of returns from these investments, which will continue beyond 2050.
- Sustainable ocean-based food production: Every $1 invested in increasing production of sustainably sourced ocean-based protein is estimated to yield $10 in benefits. The increase in demand for ocean-based protein to provide a healthy diet for 9.7 billion people by 2050, which would replace a percentage of emission-intensive land-based protein sources, can be achieved by reforming wild-capture fisheries and by increasing the sustainable production of ocean-based aquaculture. Both measures will deliver benefits such as better health outcomes to consumers, higher revenues to fishers, lower GHG emissions mitigating the risks of climate damage, reduced land-based conflicts and lower water usage.

In addition to these four ocean-based solutions, additional evidence in the literature suggests that a sustainable ocean economy can generate significant economic returns. The creation of MPAs, especially when coupled with ecotourism, substantially increases revenue for local economies. Integration of ecotourism with MPAs needs to be approached with care to avoid natural habitat degradation through over-tourism. If precautions are taken, however, the creation of MPAs can have a significant economic benefit (Figure 2.9).

The sustainable ocean economy agenda can also help catalyse land-based economic gains, especially regarding the currently wasteful plastics value chain. A systems approach to ocean plastics could result in annual savings for governments of $70 billion per year in 2040 while also reducing plastic leakage into the ocean by 80 percent compared to a business-as-usual trajectory[400]. Pioneering businesses in the circular economy also avoid financial and reputational liabilities.

Figure 2.9. Examples of Positive Economic Impacts of Marine Protected Areas



Sources: For Cap de Creus, Kas Kekova and Kuriat Islands: Mangos, A., and M.-A. Claudot. 2013. "Economic Study of the Impacts of Marine and Coastal Protected Areas in the Mediterranean." Valbonne, France: Plan Bleu. https://planbleu.org/sites/default/files/publications/cahier_13_amp_en.pdf. For Great Barrier Reef: Hand, T. 2003. An Economic and Social Evaluation of Implementing the Representative Areas Program by Rezoning the Great Barrier Reef Marine Park: Report on the Revised Zoning Plan. PDP Australia Pty. Ltd. http://dspace-prod.gbrmpa.gov.au/jspui/bitstream/11017/3376/1/Hand_PDP_Australia_2003_Report_on_revised_zoning_plan.pdf. For marine protected areas in Vanuatu and Fiji: Pascal, N., A. Brathwaite, L. Brander, A. Seidl, M. Philip and E. Clua. 2018. "Evidence of Economic Benefits for Public Investment in MPAs." Ecosystem Services 30 (April): 3–13. doi:10.1016/j.ecoser.2017.10.017; and Hand. 2003. Hunt, L. n.d. 'Economic Impact Analysis of the Cape Rodney Okakari Point (Leigh) Marine Reserve on the Rodney District', 43. https://www.howtokit.org.nz/images/emr/pdfs-files/Consultation_Resources/Hunt_2008_Leigh_marine_reserve_Economic_Analysis.pdf.

Finally, the ocean agenda can also help catalyse broader reforms in agriculture. Agricultural regulations aimed at reducing ocean dead zones could result in farmers adopting precision agriculture practices to avoid runoff. This could eventually contribute to a broader food system reform towards sustainability, which has been estimated to represent new business opportunities worth up to $4.5 trillion a year by 2030[401].

The equitable future. A healthy ocean is linked to prosperity and well-being[402]. The Blue Paper 'Towards Ocean Equity' argues that without an active consideration of equity, sustained and increased inequity will be the default outcome[403]. In the vision presented in this chapter, the sustainable ocean economy not only leads to prosperity of countries and economic sectors but also ensures adequate mechanisms for sharing the benefits of prosperity and alleviating climate change–induced inequalities. A fundamental principle of the SDGs is to 'leave no-one behind'[404]. Equality and equity considerations are implemented in the sustainable ocean economy for more than just moral reasons; they ensure the future legitimacy of the sustainable ocean economy agenda. Inequity remains a structural and persistent feature of the current ocean economy. Addressing these equity risks will counter accelerating social tensions, as well as strengthen the credibility and legitimacy of the sustainable ocean economy agenda. A recent report by the OECD, *Sustainable Ocean Economy for All*, includes a more detailed equity discussion, with a special focus on developing countries[405].

Achieving 'procedural equity'—defined as the recognition of rights and needs of all groups and the level of inclusion and participation in decision-making related to ocean development[406]—will need to be a key achievement of the sustainable ocean economy. Indigenous knowledge which is compatible with scientific conclusions will be central to a sustainable ocean economy, and will need to be made widely accessible in knowledge commons. In terms of gender equality, women today comprise only 2 percent of the world's formal maritime workforce (1 percent for sailors)[407]. By achieving gender equality, with respect to workforce participation, pay, leadership representation and advancement within a career, the sustainable ocean

Figure 2.10. Achieving SDG 14 Helps Achieve the Other SDGs

NO POVERTY

Sustainable ocean growth means sustained growth, which is able to lift and keep people out of poverty

ZERO HUNGER

Farming and fishing sustainably has the potential to produce far more protein than a 2050 population requires

GOOD HEALTH AND WELL-BEING

Apart from being able to provide more nutritious food, a healthy ocean is the recharging point for billions of people

QUALITY EDUCATION

Lifting marginalised coastal communities out of poverty increases their children's chances for a good education

GENDER EQUALITY

Increasing gender equality in the ocean economy would empower millions of women

CLEAN WATER AND SANITATION

Desalination of ocean water provides drinking water to millions of people. Additionally, improving sanitation can increase coastal water quality

AFFORDABLE AND CLEAN ENERGY

Expanding the ocean's almost unlimited renewable energy potential is predicted to contribute 10% of the global electricity production increase by 2050

DECENT WORK AND ECONOMIC GROWTH

Growing the ocean economy sustainably is projected to more than double the current ocean economy

INDUSTRY, INNOVATION AND INFRASTRUCTURE

Constructing low carbon ports and renewable ocean energy will stimulate innovation and create vital infrastructure

REDUCED INEQUALITIES

Granting well-defined ocean access rights and sustainable resource use ensures long-term prosperity of marginalised groups

SUSTAINABLE CITIES AND COMMUNITIES

Constructing blue-green storm protection infrastructure will make cities more sustainable

RESPONSIBLE CONSUMPTION AND PRODUCTION

Solving ocean plastic pollution drives us to build a more circular economy on land

CLIMATE ACTION

Growing ocean industries sustainably can contribute up to one-fifth of greenhouse gas savings towards achieving a 1.5°C future

LIFE ON LAND

Reducing ocean dead zones catalyses land-based reforms towards regenerative precision agriculture

PEACE, JUSTICE & STRONG INSTITUTIONS

In a sustainable ocean economy, a nation's sovereignty over its exclusive economic zone and resources is achieved

PARTNERSHIPS FOR THE GOALS

The ocean is a platform for collaboration and strengthens the global partnership for sustainable development

Note: Regarding SDG 6 (clean water and sanitation), the link to the ocean can be made through desalination plants. Regarding SDG 17 (partnerships for the goals), the ocean provides excellent platforms for collaboration. Peaceful ocean science collaboration, for example, has been important for diplomatic relations (e.g. U.S.-Soviet Gulf Stream experiments in the 1960s).
Source: Authors.

economy will fully unlock the productive and innovative potential of half of the world's population.

Ensuring the equitable sharing of marine genetic resources will be fundamental to ensuring a level playing field for furthering humanity's common heritage. To ensure this, the sharing of benefits from areas beyond EEZs must be based on the exchange of information, transfer of technology, capacity building and sharing of benefits arising from commercialisation[408].

Yields of many artisanal fishers have declined precipitously in recent decades, and food insecurity runs high in many coastal communities in the developing world[409]. Climate change is expected to worsen current inequalities by disproportionally affecting communities in least developed countries[410]. Building a more equal and just ocean economy will be critical for economic prosperity[411]. Empowering local fishers by granting access rights will be one of the key levers of the sustainable ocean economy. Granting access rights has already been shown to be effective: a case study from Chile demonstrates that after the introduction of territorial use rights for fisheries, artisanal fisheries gained in importance, with landings even surpassing industrial catch while recovering the biomass and size of the target species[412].

Rebuilding fish stocks and expanding non-fed aquaculture would significantly contribute to the alleviation of malnutrition (undernutrition and nutrient deficiency). Young children (<5 years) bear the burden: an estimated 150.8 million children are currently stunted (low height for age), another 50.5 million have weight too low for their age and 38.3 million are overweight[413]. Seafood contains critical trace minerals, omega-3 fatty acids, iodine and other micronutrients and vitamins crucial for healthy development[414]. These key nutrients could also help to reduce the 11 million annual deaths related to poor diet[415] if consumers shifted their eating habits to include healthier and more nutritious options, such as seafood[416]. Indeed, the IPBES states that 'shifting diets towards a diversity of foods, including fish, fruit, nuts and vegetables, significantly reduces the risk of certain preventable non-communicable diseases (e.g. cardiovascular diseases, cancers, diabetes), which are currently responsible for 20% of premature mortality globally'[417].

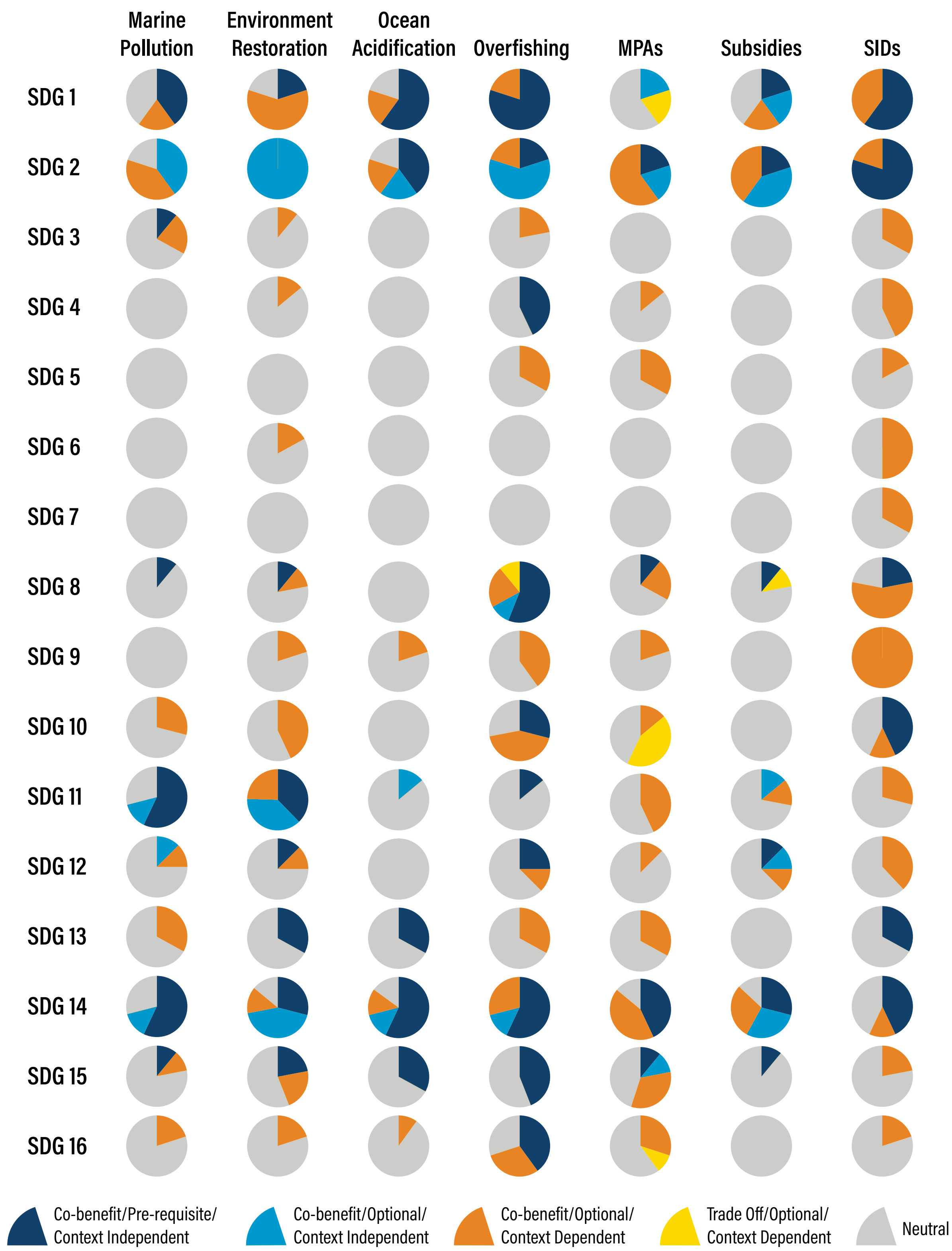
The development of transparent supply chains and international collaboration can significantly reduce maritime crime. Transparent supply chains can minimize IUU fishing, leading to increased food provisioning to marginalised communities (often the worst affected). Other fisheries-associated crimes can be reduced by stronger international cooperation: the adoption and implementation of the International Declaration on Transnational Organized Fisheries Crime in the Global Fishing Industry must lead to reductions in forced labour and in the smuggling of people and contraband.

A celebrated ocean. 'Happiness is among the most fundamental of all human goals'[418]. Millions of people a year travel to the ocean to enjoy themselves—an estimated 120 million are estimated to annually engage in marine recreational activities like diving, whale watching or recreational fishing[419]. A sustainable ocean economy would be able to maintain the healthy ocean required for ocean recreation.

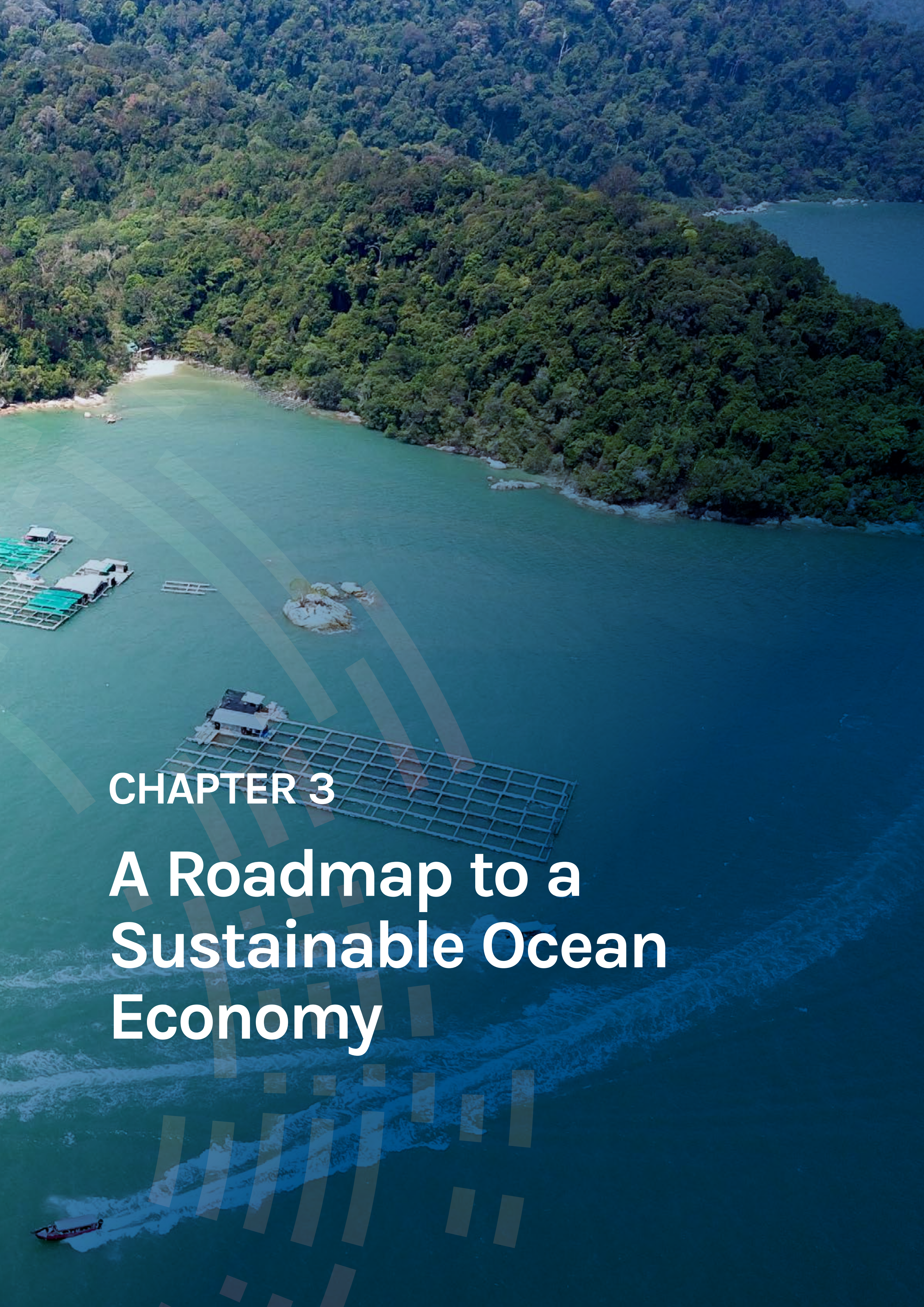
Apart from providing leisure, the ocean is central to the aesthetic, religious and spiritual ways of many cultures[420], especially Indigenous ones. A healthy ocean is essential to the maintenance of its immense cultural significance. MPAs and other effective area-based conservation measures can help preserve pristine and culturally important ocean areas (e.g. sacred sites, historic wrecks and associated war graves). In ocean areas where the sustainable extraction of resources by Indigenous groups is a key aspect of their culture, their rights to secure access and control should be guaranteed.

The ocean in service of the SDGs. Building a more protected, productive and prosperous ocean economy offers solutions to accelerate other Sustainable Development Goals (see Figures 2.10 and 2.11)[421]. Replenishing and sustainably managing the ocean will be a significant part of achieving SDG 2 (zero hunger). A more sustainable ocean produces more food indefinitely[422]. The ocean's immense wind energy potential[423] advances the energy independence goals of SDG 7. Addressing ocean-based pollution could catalyse land-based reforms towards achieving SDG 15 (life on land) and push the world towards more responsible production and consumption, SDG 12. A study examined the relationship between SDG 14 targets and other SDGs at a more granular level, detailing the link, co-benefits or potential trade-offs[424]—see Figures 2.10 and 2.11.

Figure 2.11. Detailed Relationship between SGD 14 Targets and Other SDGs



Source: Singh, G.G., A.M. Cisneros-Montemayor, W. Swartz, W. Cheung, J.A. Guy, T.-A. Kenny, C.J. McOwen et al. 2018. "A Rapid Assessment of Co-benefits and Trade-offs among Sustainable Development Goals." Marine Policy 93 (July): 223–31. doi:10.1016/j.marpol.2017.05.030.



CHAPTER 3

A Roadmap to a Sustainable Ocean Economy

Introduction

Chapter 1 makes an urgent case for action: the ocean is vital for humankind and the entire economy, current ocean management struggles to deliver on the dimensions of protection, production and human prosperity, and more and more successful sustainable stories and pioneers are in desperate need of support and scale-up. Chapter 2, which shows how ocean protection and ocean productivity can serve each other, outlines an alternative, generalised 'triple win' future. The case for a healthy ocean supporting a healthy economy is well documented. So why is this so hard? Why isn't the sustainable ocean economy at the centre of all the post-COVID recovery discussions and financial stimulus packages? How can this urgently needed shift be accelerated?

The global struggle against climate change is both immediately relevant and in an analogous stage. The science is compelling; consequences are rigorously documented (IPCC); the cost of inaction is quantified, as is the business case for change; pledges are in place (UN Framework Convention on Climate Change/Paris Agreement); a majority of people find this to be the defining crisis of their lives; investors are starting to move away from fossil fuels. And yet, progress is falling short: the UN Environment Programme's *Emissions Gap Report 2019* states that the world is heading for a 3.2°C global temperature rise over pre-industrial levels[425], far beyond the 'below 2 degrees' target.

The relationship between the ocean and humanity goes both ways—one shapes the other. In this classic 'complex adaptive system'[426], the biological, chemical and physical ocean responds to an array of human forces which, in turn, are shaped by regulation, taxation, financial interests, consumer preferences, historical legacies, and diverse traditions and cultures. Any change in a system of such complexity, almost by definition, has unforeseen and complex consequences. For climate and the ocean, the implicit and explicit rules are based on the lessons of the past, not the future—and they are legally, politically and culturally entrenched and protected.

How, then, can the shift be accelerated from the urgency of Chapter 1 to the more hopeful future of Chapter 2? At a time when governments are actively looking for solutions to recover from the COVID-19 shock, how can the integral role of the sustainable ocean agenda in rebuilding a more sustainable, resilient and just economy be ensured?

This final chapter focuses on the 'how' and provides a roadmap addressing the following questions:

- What are the barriers to change, and what lessons from the experience of similar industrial and societal transitions could be applied to the ocean economy? (Section 3.1)
- What main transitions are required and how can this sustainable ocean economy agenda be structured? (Section 3.2)
- What catalytic interventions can help enter an upward spiral? (Section 3.3)

3.1 Harnessing Complex Adaptive Systems: Lessons for the Sea

The social, economic and ecological systems in the ocean realm connect into a complex adaptive system, where the 'behaviors of individual actors at the local scale influence interactions and emergent properties at the regional or global scale. Emergent properties, in turn, can feed back to the small scale and influence subsequent behaviors of the individuals'[427]. This complexity can explain why the current model of ocean management exists and is so hard to transform. But the adaptability also leaves room for evolution if the mechanics and incentives are changed, and if feedback loops are switched from vicious to virtuous.

This section first describes the barriers which have made the pace of reform appear timid and slow. Learning from other socioeconomic and industrial transitions, this section then identifies a framework that could be used for a successful transition towards a sustainable, more equitable ocean economy.

Major barriers to a sustainable ocean economy

The complex adaptive system of the ocean economy is shaped today by strong incumbent interests, cultural norms, institutional constraints, policies and laws. In this status quo, the feedback loops and incentives are driving behaviours that hinder a transition towards a truly sustainable, regenerative ocean economy. These incentives can be of different kinds: economic, reputation-driven or personally motivated social norms[428]. In the current ocean economy, these incentives share a common feature: they ignore or vastly discount environmental and social impacts. To shift these incentives towards alignment between effective protection, sustainable production and equitable prosperity, the first step is to dissect some of their main root causes, presented here as six systemic barriers (Figure 3.1).

Figure 3.1. Main Barriers to a Sustainable Ocean Economy

- Institutional inefficiencies
- Lack of planning and integration among sectors
- Concerns about stranded jobs and communities
- High costs of capital
- Suboptimal market dynamics
- Subjectivity and irrational behaviours

Source: Authors.

Institutional inefficiencies. A complete description of the ocean-related institutional structures and agreements is beyond the scope of this report, but some inefficiencies can be listed here: complexity of governance, lack of overarching mandate towards a healthy ocean and rigid and static processes poorly informed by science.

Complexity of governance. International ocean management is a web of intertwined, converging and competing demands and interests[429] involving no fewer than 576 bilateral and multilateral agreements[430], which are administered by a multitude of institutions with widely varying mandates, resources, authorities and capacities (Figure 3.2).

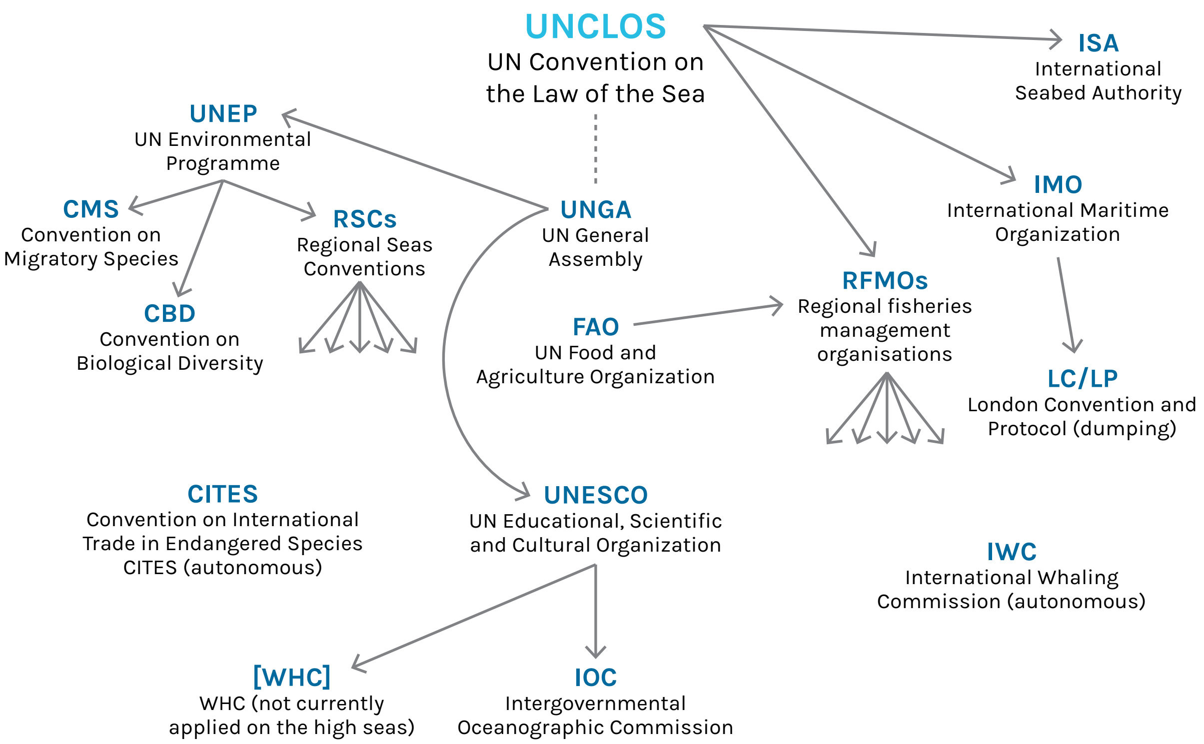
'Polycentric governance', that is, governance that includes multiple centres of semiautonomous decision-making, can be an efficient model to manage at a global scale a complex adaptive system like the ocean[431]. Polycentric models indeed allow decision-makers to 'experiment with different governance solutions tailored to particular scales and socioecological contexts'[432]. However, if collaboration, transparency and clear mandates are ill-defined, polycentricity can be a double-edged sword and limit efficiency and capacity for change and more sustainable management.

At the global level, the exact reach and authority of even well-established ocean organisations based on global treaties is often unclear. For example, the extent of the International Whaling Commission's legal competence is in dispute, with some nations restricting it to great whales (baleen and sperm whales), while others include all cetaceans. In many cases, individual nations claim exceptions to specific articles of the convention, while still remaining members. As another example, the ongoing negotiations on biodiversity beyond national jurisdiction are exceptionally important but unlikely to call for a new international framework for ocean governance under the UN umbrella. Nevertheless, there are also examples of well-functioning international frameworks. High-level international forums such as the Arctic Council and the Parties to the Nauru Agreement focus more on pragmatic advantages of cooperation (such as shipping safety in the Arctic or cooperation in tuna stock management) than the painstaking process of formal treaty negotiation.

Lack of overarching mandate towards a healthy ocean. Most of the ocean-related institutions have been established to support the development of a given ocean-based sector. This development has usually been assessed against conventional and incomplete metrics like sector revenues (or GDP) or number of jobs. These institutions are rarely driven by an overarching mandate that would transcend the sectorial silos and also aim to achieve healthy ocean ecosystems (see the next barrier, 'Lack of planning and poor integration among sectors').

Rigid, static poorly science-informed processes. In most cases these ocean institutions are not equipped to pilot

Figure 3.2. Institutions and Frameworks That Support the UN Convention on the Law of the Sea



Source: Adapted from Ardron, J.A., and R. Warner. 2015. "International Marine Governance and Protection of Biodiversity." In Routledge Handbook of Ocean Resources and Management, edited by H.D. Smith, J.L.S. de Vivero and T.S. Agardy, 55–72. London: Routledge.

the management of a complex adaptive system. Because they depend on laws and/or consensual decisions that take time to change and reform, they usually deliver their mandate in a static fashion, and react a posteriori to shocks and unexpected events. As stated above, social, environmental and economic systems are intertwined in a complex adaptive system whose proper governance requires adaptability and agility. Besides, the management of the ocean today is not informed enough by solid science, and personal or national interests can often outweigh recommendations from the scientific community. The upcoming UN Decade of Ocean Science for Sustainable Development is a great opportunity to strengthen this science-policy interface.

International fisheries are a good example of many of these institutional inefficiencies. Myriad bilateral, trilateral and multilateral fisheries management agreements and regional fisheries bodies exist. However, for the high seas, only the 16 regional fisheries management organisations (RFMOs) are mandated through the UN Fish Stocks Agreement to adopt legally binding measures. The RFMOs differ widely in their funding, scientific capacity, relative authority with member states and, ultimately, fishery outcomes. Since decisions are generally made only based on (near) unanimity among member states, the process can be slow and somewhat weighted towards avoiding losses by individual states, rather than optimising the fisheries or ensuring healthy ocean ecosystems[433]. Co-operation among RFMOs is improving, and even though discrepancies in performance and transparency of RFMOs remain[434], several of them are more closely following the conclusions of their scientific committees. Even if more than an RFMO, the ecosystem monitoring program of the Commission for the Conservation of Antarctic Marine Living Resources, which applies the precautionary principle and commits to 'best available science' standards in its management of krill and finfish restoration efforts[435], may be an example of better management practices, although it, too, needs improvements. The steadily improving data transparency on fisheries driven by FAO is also leading to broader reforms.

Lack of planning and integration among sectors. Ocean development, so far, has largely occurred ad hoc. When communication among the food, energy and shipping sectors does occur, it is more often about conflict resolution than symbiosis and collaboration.

Formal coordination remains rare, since ocean sectors are often governed by different regulating entities, making cross-sectoral communication and planning difficult. As of today, only 22 countries[436] systematically assess the efficient, safe and symbiotic use of the ocean's resources—its power generation, biological productivity, carbon sequestration and so on. Typically, such a planning process provides guidance on the integration of ocean uses, avoidance of spatial use conflicts, standards of operation, streamlined and efficient regulatory process, and the overall protection and sustainability of the key oceanic systems. It is sometimes supported by new incentives ('carrots' or 'sticks') including public sector demand and offtake guarantees, feed-in tariffs, infrastructural support and public participation in the required investments.

Without such a process, ocean economy sectors are left to compete in an operational and regulatory vacuum. Even fully mature technologies, such as offshore wind farms, often struggle in such a regulatory environment; for example, the offshore wind industry along the U.S. Eastern Seaboard, despite compelling economics and ample demand, has been mired in regulatory setbacks for the better part of a decade. Innovative concepts—such as multi-trophic farming, co-location of fish and seaweed farming, and the use of offshore wind energy to produce shipping fuels (hydrogen and ammonia), power large-scale aquaculture or power desalination plants—are very difficult to realise without integrated planning, explicit national priorities, regulatory support and time-tested emerging technology incentives.

Concerns about stranded jobs and communities. A sustainable ocean economy looks very different from today and implies real structural shifts—such as the reduction of fishing fleets and jobs, on the one hand, and the increase of wind energy and mariculture jobs, on the other. Many coastal communities are built around fisheries and fishery-related jobs that constitute their heritage and social glue. Some of these communities may find themselves disadvantaged by this transition: economically speaking, they may not be able to find alternative sources of income overnight, potentially causing significant short-term equity issues; culturally speaking, it will be very hard for these communities to give up on decades or centuries of social norms centred on traditional activities. Their concerns are entirely legitimate and clearly require public support, guarantees and a transparent and inclusive dialogue.

A good example is in fisheries. Global current fishing capacity is estimated to be between 1.5 and 2.5 times more than what is needed to fish under maximum sustainable yield[437]. To rebuild global fisheries, millions of the current 4.3 million fishing boats need to be decommissioned at a global scale, and between 15 and 22 million fishers (assuming linearity, which is probably simplistic) would need to shift to other pursuits[438]. However, fishing jobs do not convert easily, and alternative wages tend to be low[439]. The economic challenge is real but not insurmountable if proper solutions, support and compelling change management are put in place. For instance, 75 percent of fishers in Hong Kong would be 'willing to leave the industry if suitable alternatives or compensation were available'[440]. Similar sentiments are likely to arise in other countries[441]. Cultural and spiritual dimensions need to be seriously considered, however, as in some communities fishermen do not want to leave fishing—even if suitable alternatives exist.

High costs of capital. The cost and availability of capital is a serious constraint across the spectrum of ocean enterprise. The latest data from the IEA (2019), for example, show that the levelised cost of electricity (LCOE) from offshore wind is reduced by 30 percent if the weighted average cost of capital is reduced from 8 percent to 4 percent[442]. This clearly shows the importance of creating access to stable financing. Capital-intensive ventures such as ocean-based renewable energy and large-scale mariculture encounter technical, infrastructural and regulatory challenges, which grow exponentially with the distance from shore—precisely where most large-scale food and energy production could be sited. Key technologies may not yet fully be tested in the cauldron of open ocean conditions and intensifying storms. Onshore competition, such as from onshore wind, freshwater aquaculture and alternative proteins, is a source of considerable uncertainty. Lastly, there are many potential sources of use conflicts and attendant regulatory risks and delays. The sum of these risks leads to capital premiums, and many institutional investors may stay away altogether. There is no shortage of innovative thinking, concepts, blueprints and business plans in the sustainable ocean economy—but the leap from concept to reality is harder in the ocean than it is on land.

On the less capital-intensive side of the spectrum, financing issues also loom large. In fisheries, for example, real or implied discount rates are high. Artisanal fishers often do not have the luxury of planning for tomorrow's catch. Even in more organised commercial fishing, open-access laws and overcapacity lead to a 'race for fish' that heavily discounts future yields. The current market-hunt nature of wild-catch fisheries is very difficult to fit into an investment structure requiring legally robust, long-term ownership of future cash flows. The same dynamics have made the financing of fishery recovery efforts especially difficult, and terrestrial crop insurance mechanisms have, by and large, not been translated to fish stocks. Except at unsecured, very high rates, small fishers in the developing world have little access to the capital needed to build port-side infrastructure, develop efficient transportation and value-adding processing, buy safer boats and prepare long-term management strategies.

Suboptimal market dynamics. The tragedy of the ocean commons can be quite pronounced, with some economic rents procured at the expense of overall system health and productivity. Too often, legal or regulatory recourse is elusive when one nation overfishes at the cost of another, when land-based polluters harm fishers, or when climate change destroys reefs that protect communities. The gains (mostly terrestrial interests) and losses (mostly ocean interests) can be in the billions of U.S. dollars (see examples in Chapter 1). In many cases, these characteristics of the system prevent change towards sustainability—for example, regional fisheries management organisations have been seen to allow member countries to block reforms, even when the economic and scientific rationale is compelling; terrestrial polluters are still mostly legally indemnified from their ocean liabilities; and the international vessel registration system is designed to allow the origins of economic and legal ship ownership to be separate. These can be significant hurdles to overcome on the way to reform.

Existing laws often protect incumbent interests. Open access to ocean resources is enshrined in law, culture and convention—in many developing countries, it is regarded as a constitutional right of artisanal fishers, even if it makes local ownership and stewardship nearly impossible. International law enshrines the right to fish, free passage and open access to open ocean resources. Open access may appear equitable, but it often leads to a race for resources which ultimately favours depletion and inequalities over stewardship. Similarly, parties who are making the investment in sustainably managing a resource do not always reap the benefits of their investment, as in the case of highly migratory fish species that cross multiple EEZs during their lives. If one country invests in species management within its EEZ, other countries benefit from this investment—through the free-rider effect—due to increased catches. The potential free rider's overfishing behaviour of the shared stock could nullify any efforts by the investing country once it reaches that country's EEZ.

Subjectivity and irrational behaviours: (Not) making sense of the largely unknowable. Subjectivity and irrational behaviours conspire against systems thinking and the transition towards a sustainable ocean economy. A number of individual behaviours can be explained by cognitive biases, which result from simplifications the human brain does to make decisions out of complex information. For instance, humans tend to react to the possibility of highly worrisome news (such as a scenario describing a potentially catastrophic future) by seeking to confirm the belief that they are safe—and they are much more likely to believe those peers who confirm this belief (called 'confirmation bias'). This bias is easily exploited by those who use the inherent uncertainty of ocean state predictions to invalidate them. Confirmation bias is exceedingly difficult to overcome with new scientific information alone—it needs to be addressed on a cultural level. Similarly, when faced with the need for reforms which require short-term sacrifice for long-term gain (as is the case with many fishery reforms), humans tend to systematically overvalue present over future assets—even when (rational) discount factors are included. From a systems perspective, this can all amount to a hard-to-break feedback loop: bad habits are systematically re-enforced by the very system they shape. This bias is reinforced by short political cycles: many coastal and ocean decisions being made in the present have time horizons of decades to over a century, far longer than the lifespan of the governance arrangements facilitating them.

Any person's decision-making is hard—it needs to weigh long-term over short-term return, the value of different forms of wealth (financial, natural, cultural and personal) now and in the future; risk and peace and security, status, cultural and religious norms and so on. In many countries, cultural, legal and religious norms re-enforce a view of the ocean as both inexhaustible and commonly owned, with the spoils going to those who 'brave the sea' and take risks. Thus, understanding people's values and resulting emotional responses is critical in a system transition. Legal norms pertaining to activities taking place on the ocean tend to be weaker than those on land, and less enforced. Ownership of ocean resources tends to be far less defined, and far less definable, than on land.

On the positive side, these (subjective) personal incentives can also be used for good: altruism, ethical values, reciprocity and other types of intrinsic motivations can become powerful drivers of positive change[443]. Enhancing reputation and brand image can also be a strong incentive for businesses or governments to proactively lead on sustainable practices[444].

To move the system, it is important to learn from other system transitions

Despite barriers, even very complex adaptive systems can shift onto new trajectories—sometimes very quickly. Economic history is replete with examples. When new information is plentiful and there is strong support for change, the shift can be entirely designed and purposeful—such as the energy transition in Germany, the Global Vaccine Alliance, smoking bans in bars and restaurants in Ireland and France, or the Montreal Protocol on Substances That Deplete the Ozone Layer. Even in the absence of new information or strong support, shifts can happen—sometimes they emerge from a new framing of an older issue (non-traditional marriage in the United States) or they take a less obvious, emergent form (such as the downward trajectory of meat consumption per capita in OECD countries in the past decade[445]). Deriving key success factors from these shifts as well as from the latest literature on system transitions[446], a framework for a transition towards a sustainable ocean economy can be articulated (Figure 3.3).

The first building blocks of this transition framework are three fundamental shifts in the established socially constructed order (top layer in Figure 3.3). These shifts are expected to create new conditions and social norms that incentivise a company, a country or individuals to modify their way of interacting with the ocean in favour of more sustainable and equitable behaviours:

- **Balanced top-down / bottom-up governance.** Major shifts in the way a complex adaptive system behaves rarely occur in an entirely purposeful, 'top-down' fashion. This is certainly true for the shift towards a sustainable ocean economy, where a multitude of (hard to predict) feedback loops can jeopardise the goals of a purely top-down approach.

  Top-down governance, to be sure, is essential. Land use, for example, is governed by a much more structured system of product and operating standards, clear access and property rights, the provision of legal recourse and so on. In many cases, top-down rule setting has launched, rather than shackled, global industries. Today's thriving telecom industry, for example, would not exist without compatibility of transmission formats, a global process for frequency allocation, consolidation limits and so on. A global pharmacological market could not exist without global testing and production protocols. The internet protocol (TCP/IP) is at the heart of much of today's commerce. A modified, ocean-relevant version of such protocols, rights and obligations is essential for the difficult, risky and capital-expensive development of a sustainable ocean economy. Investors are sure to require long-term resource access guarantees, reliable regulatory protocols, standardised transfer points, and clear operating and performance standards. Yet this top-down governance needs to become more adaptive, faster and more deeply connected to communities. In recent years, the lines between the 'top down' and the 'bottom up' have often become blurred—

Figure 3.3. Framework for a Successful Transition towards a Sustainable Ocean Economy

Source: Authors.

generally to very good result. The Paris Agreement, for example, blends a voluntary commitment structure with a centralised monitoring, reporting and verification function.

Bottom-up governance and grass-roots movements have been transformed by digital communication. For example, fishing communities in the Philippines are now collaborating in turning their local experiments with territorial use rights into a regional and national movement—by collaborating in the alignment of regional and national fishing policy with local needs, in obtaining financing for their fleets at favourable (joint) rates and offering education to other communities interested in joining the movement. As the movement grows, local collaboratives assume quasi-governance functions and authority—a welcome development.

- **(Digital) knowledge access generalised for all.** It is predicted that by 2020 data generation will increase annually by 4,300 percent[447]. Digitalisation provides rare, necessary open spaces for experimentation and innovation towards more sustainable, equitable management of the economy[448]. Some examples in the literature define *open source* (freely, publicly available information, data or software): 'When open source principles prevail, countless inquiring eyes can scrutinize everything—the infrastructure, the transactions, the dialogues, the individuals—which minimizes the opportunities for quiet subterfuges and backroom deals'[449]. The processes of governance are more likely to be honest and fair, and be seen as such[450]. For instance, in the ocean economy realm, critical data on storm tracks, market pricing, logistics, demand and the like have increasingly become available even to the smallest fishers and according to Bollier 'could help usher in new, more ecologically benign forms of decentralized production and consumption'[451].
- **Ocean stewardship enabled by new frameworks and partnerships**. Stewardship actions have been defined as 'the suite of approaches, activities, behaviors, and technologies that are applied to protect, restore or sustainably use the environment'[452]. The concept proposed here is to empower the ocean economy players (fishers, communities, businesses, etc.) to better manage shared ocean resources. For instance, the territorial use rights for fisheries (TURFs) system, in Chile, the Philippines and Indonesia has bestowed exclusive control of local fishing grounds to coastal communities—which have generally responded with much improved resource stewardship[453]. Similar stewardship initiatives can be found in the business world: CEOs from the 10 largest global seafood companies (including fishing, aquaculture and aquafeed manufacturing) have joined forces through Seafood Business for Ocean Stewardship (SeaBOS), with the strong belief that through engagement with keystone actors, it is possible to both raise the sustainability bar for global companies that have significant influence within their industries and provide incentives for smaller companies to catch up with their peers[454].

At the surface, each of these new social norms sounds obvious—in practice, they can be controversial and hard to implement because of the barriers mentioned above. For this reason, these fundamental shifts need to be supported by two core elements:

- **An action agenda** (middle layer in Figure 3.3). Major shifts can happen ad hoc, but it's better to have an agenda. Industrial strategy agendas, for example, were a mainstay of public policy before 1990, briefly fell out of favour during the early digital revolution and are now making a major comeback with China's massive Belt and Road initiative, Britain's Industrial Strategy, Germany's Energie Wende and similar efforts. Shifting the commodity value chains (palm oil, tropical wood products, wild-caught and cultured fish, etc.) towards sustainability was the result of very deliberate agendas designed by NGOs, major buyers and government agencies. The Arctic Council's vision for risk-managed and sustainable development in the Arctic Ocean is based on a deliberate, shared, multinational agenda.

  In the context of this report, such an action agenda offers a clear, holistic picture of the various components of ocean economy reform, builds on emerging innovations and front-running projects and aims to scale them up. Section 3.2 lays out this agenda in detail—the case for change, the feasibility and the concrete opportunities for action.
- **A robust delivery mechanism** (bottom layer in Figure 3.3). Delivering the action agenda can appear quite daunting for any decision-maker or national leader. This report identifies three complementary levels of intervention to start or accelerate the journey towards a sustainable ocean economy. They do not pretend to be exhaustive solutions, but they offer some options to be considered by decision-makers (particularly policymakers):

  1. Local, catalytic interventions are essential to create support from the base and demonstrate tangible results on the ground—seeing is

believing. Section 3.3 elaborates on a concept of small ocean 'special use' areas, which could be used as laboratories and demonstrators of a sustainable ocean economy.

2. National, coordinated 'ocean task forces' should be established. Using the best practices of performance management inspired by decades of practice in the private sector, they should deploy the implementation of the ocean agenda at the country level. Section 3.3 elaborates on the key features of such ocean task forces.

3. International leadership will be needed in various forms: ratifying and enforcing international treaties, conventions and agreements (such as the upcoming legally binding instrument on biodiversity of areas beyond national jurisdiction, or the Port State Measure Agreement to fight IUU fishing), or promoting new international public-private partnerships to advance knowledge and best-practice sharing, and remove roadblocks to the implementation of a sustainable ocean economy (see Section 3.3).

3.2. Charting a Direction: The Ocean Action Agenda

Change will not come with the stroke of a pen, or through a normative policy process only. The conditions for a top-down approach—predictability, enforceability, high levels of support, abundant feedback from diverse sources—are simply not in place, and a different, much more networked and adaptive process must be used. But just as clearly, the sustainable ocean challenge cannot be left to itself—a plan, an agenda is needed.

It is not necessary to start from a clean sheet though: the outline is in place in terms of governance and policy, technologies and business models, international collaboration and new consumer demands (see Section 1.3).

This section proposes an action agenda to deliver the overarching mandate of effective protection, sustainable production and equitable prosperity; this action agenda is based on five cross-cutting enablers, which collectively will help five main sustainable ocean sectors to thrive.

These 10 components cannot be seen or advanced in isolation. Like the system they aim to change, these components are highly interconnected. The enabling conditions can support each other (e.g. better data in support of de-risked finance, smart planning and upgraded ocean accounting), and the sectors have to develop in harmony with each other to exploit synergies (clean energy from offshore wind farms to fuel green ships; co-location of MPAs and offshore wind farms; co-location of seaweed, bivalves and finfish mariculture farms; MPAs to provide nursery grounds for fisheries, etc.; see arrows in Figure 3.4).

This agenda stands on the shoulders of good work already done but provides a powerful new boost towards a truly sustainable ocean economy. This action

Figure 3.4. One Mandate and 10 Components of the Action Agenda for a Sustainable Ocean Economy

Five cross-cutting enablers for a sustainable ocean economy

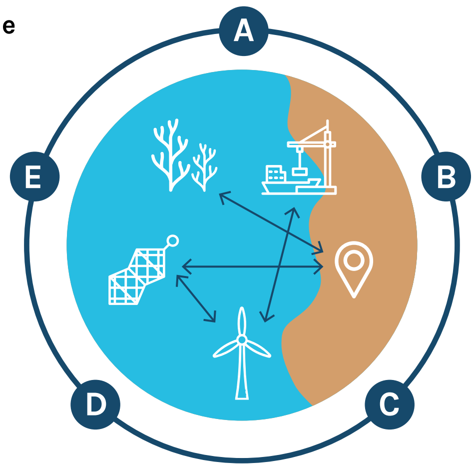
A) Data reform

B) Goal-oriented ocean planning

C) Innovative finance and de-risking

D) Stopping land-based pollution

E) Upgrading ocean accounting



Five key sectors to be transformed towards a sustainable ocean economy

Sustainable ocean food production

Clean ocean energy

Low carbon transportation and ports

Ocean restoration and protection

Tourism

Source: Authors.

agenda recognises the inherent challenges associated with a transition of such scale and would also have to be adapted to fit local, national or regional contexts. The OECD report *Sustainable Ocean for All* is a valuable source of insights regarding the specific challenges faced by developing countries seeking to embrace a sustainable ocean economy agenda.

Five cross-cutting enablers for a sustainable ocean economy

After extensive review of Blue Papers commissioned by the High Level Panel for a Sustainable Ocean Economy, scientific literature and expert consultations, five cross-cutting topics crystallise as the core enablers to provide the right conditions for a sustainable ocean economy to thrive (left-hand side of Figure 3.4 and Figure 3.5):

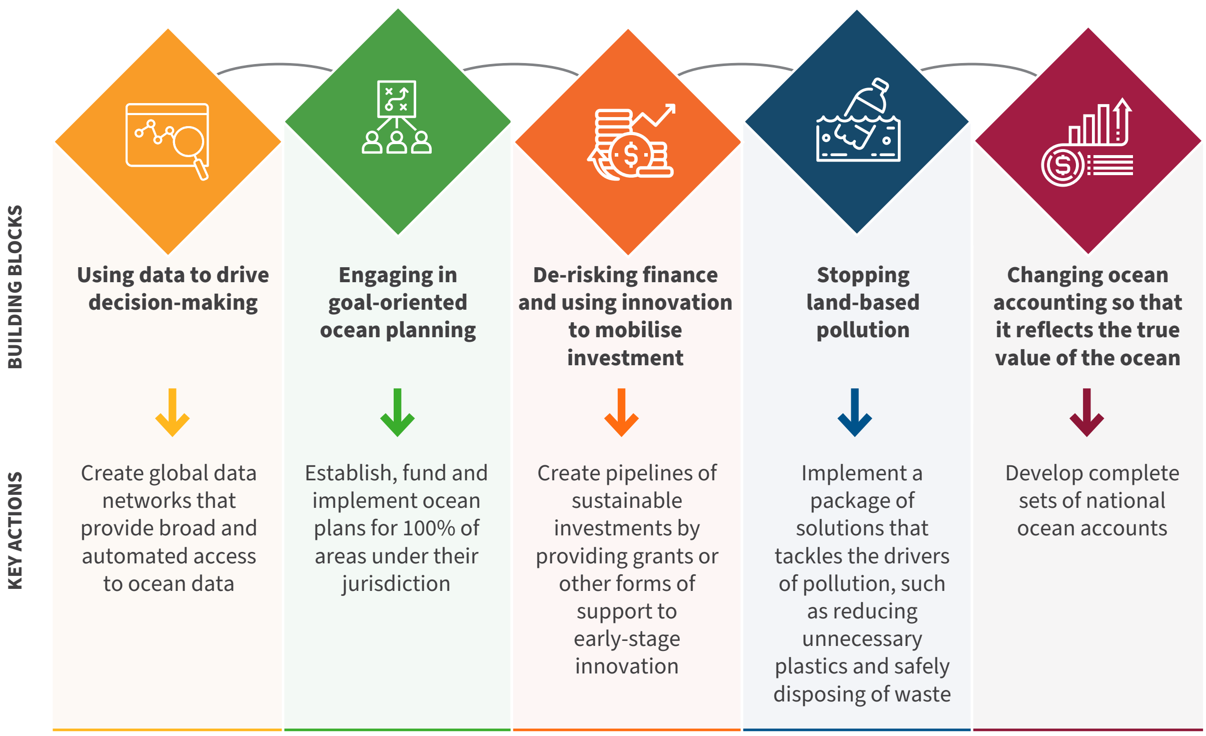
Data reform: The revolution in data production (enabled by new technologies), collection and management (sensing, tagging, sharing), processing (simulation, forecasting, optimisation, tracking, process management) and sharing (open data platforms) can have a profoundly positive impact on all aspects of the ocean economy. This will require a comprehensive reform of currently proprietary sensing, storage and application methods.

Goal-oriented ocean planning: Explicit guidance towards the overarching mandate (protect effectively, produce sustainably and prosper equitably) is required to ensure the avoidance of spatial use conflicts, uniformly high standards of operation, a streamlined and efficient regulatory process, the integration of symbiotic ocean uses, the overall protection and sustainability of the key oceanic systems, the efficient management of fishing rights and a just transition for workers of the ocean economy.

Innovative finance and de-risking: Potential sustainable economy investors (sovereign wealth, institutional) require basic guarantees on infrastructure access and pricing, long-term access rights, regulatory certainty, reliable operating standards and solid legal recourse options. These are not uniformly in place today. Public financing might be required to mitigate inherent costs required to kick-start a sustainable ocean economy.

Stopping land-based pollution: The sustainable ocean economy cannot thrive if land-based pollution ending in the ocean is not significantly reduced through ambitious and systems-inspired reforms.

Figure 3.5. Five Building Blocks Are Key to Creating a Sustainable Ocean Economy



Source: Authors.

Upgrading ocean accounting: A sustainable ocean economy needs to be piloted through a holistic set of metrics which measure flows and stocks, economic and natural capital.

These five enablers can set up new rules and a favourable environment in which a sustainable ocean economy can develop. In particular, five sectors are reviewed in depth in this section, as the future champions of a sustainable ocean economy (right-hand side of Figure 3.4). For each of them, this report analyses why such a sector needs to be transformed and identifies some concrete opportunities for action that could be taken to capture the full sustainable potential of these sectors.

Sustainable food from the ocean: How the provision of healthy, low-carbon and nutritious food can be scaled while regenerating the ocean ecosystems and better redistributing benefits.

Clean ocean energy: How societies can be powered by harvesting renewable ocean forces.

Low-carbon transportation and ports: How national and international transportation of goods and people can be provided in a climate- and biodiversity-friendly, socially acceptable way.

Ocean restoration and protection: How insufficient, isolated activities can be turned into a thriving sector, generating jobs, revenues and numerous ecosystem services.

Tourism: How the beauty of coasts and the ocean can be enjoyed while restoring them.

This section explores each of these areas in terms of their importance, their path dependencies and barriers and, most important, opportunities for action.

Data reform: How could the data revolution—enabled by new technologies—change the way informed decisions in the ocean realm are made?

Why is it important?

The data explosion—in other words, the rapid increase of data and information created and made available—can reshape understanding and management of the ocean. The ocean is notoriously reluctant to reveal its secrets—far too little is understood about the interface between humans and the ocean ecology. New sensing, data management, visualisation, simulation and modelling technologies can change that—but current sharing practices are not yet fit for purpose.

In the near future, every ship's journey, and the nature of its business at sea, will be public information. Lawbreakers such as illegal fishers, polluters, smugglers and labour law violators will literally be on the public radar and subject to arrest. The Sea Around Us[455] project, for example, is providing entirely new levels of transparency on the state of the world's fisheries, while Global Fishing Watch[456] visualises, tracks and shares data on global fishing activities in near real time.

New ledger technologies can register ocean-related rights and contracts, both for public titling and private contracts, which opens up new horizons in rights-based management[457]. Product tracking throughout the chain of custody can help brands embrace sustainable practices[458] and would help small producers connect to global supply chains.

For ocean resource managers, replacing trial-and-error methods with reliable simulations lowers feedback and response times from years to hours, and allows quick insight on how the ocean reacts to specific inputs, rules and incentives. A number of these 'flight simulator' efforts are now in development for applications ranging from fishery management to ship routing and ecosystem conservation. The POSEIDON model[459], for example, simulates the feedback loop between fishery policies, fishing fleets and ocean ecosystems, allowing for real-time testing of policy alternatives. These applications will allow managers to adjust to changing conditions[460], such as dynamic management of fishing areas and quotas, ship traffic adjustments or avoidance of endangered species bycatch[461].

What is preventing (faster) change?

Four main obstacles currently prevent the full capture of this potential.

- **On the technical side**, ocean sensors require power, which is hard to obtain for anything but the slowest-moving device. Undersea communications, unable to use electromagnetic waves, are notoriously challenging. The analytical methods required to harness the data into nimble, robust and transparent ocean management systems are complex and underdeveloped. Another technical challenge relates to the origin of data, which in some cases will not simply come from high-tech connected sensors but will have to be extracted from paperwork and measurements done by hand.

- **More daunting are the institutional, political and analytical challenges**. The fragmentation of ocean data into national, corporate and academic fiefdoms is a huge problem. Data inequities abound, with poorer nations and resource users largely excluded from the data bounty. And most important, oceanic data collection is still very expensive, with most sensors custom-built for narrow and specific scientific missions[462]. Technological innovation in the ocean has therefore been largely driven by government and large-scale commercial interests. Many needs remain simply unserved.
- **Financing has been difficult.** Much of ocean technology has relied on the trickle-down of commercial (mostly oil and gas) and defence technologies. National R&D expenses dedicated to ocean science vary greatly from country to country (21.4 percent in Argentina, over 2.5 percent in the United States, 0.1 percent in Russia)[463], but they can generally be considered as too low. Data collection in the harsh ocean environment is expensive—even medium-sized research vessels have operating budgets above $20,000 a day, with some globally operating vessels having budgets as high as $40,000 a day[464]. A business-as-usual approach will not come close to paying for the needed ocean technology.
- **Lastly, there is a capacity issue.** Even when relevant data are available, managers often do not get the information they need because of data access restrictions, or because they do not have data scientists to address the most policy-relevant questions[465]. Decision-support tools designed explicitly for marine managers are often so technical that only programmers are able to use them[466]. For example, fishery management in data-poor, developing-country environments often requires sophisticated data extrapolation techniques and extensive adaptation of standard analytics to local conditions.

What are the opportunities for action to overcome these barriers?

Data management is evolving towards a ‘digital ecosystem for the environment’[467]—a systemic, dynamic and collaborative model[468] that aggregates data into entirely new levels of synthesis, visualisation and managerial utility. This model uses huge networks of cheap, standardised and connected sensors (an ‘Internet of Things for the ocean’[469]) with no regard to specific, predetermined purpose. These networks deposit data into unstructured data ‘lakes’ which enable users to build their own knowledge systems. This approach has already transformed machine learning and analytics, democratising the data[470] and allowing for the massive economies of scale needed to understand the ocean in all its complexity.

Universal data tagging standards are essential to allow data to be combined in federated data networks and data lakes that support verified and automated global access[471]. Governments can lead the way directly by taking bold steps to mandate these standards and to help create and contribute to federated data networks[472]. They can also require data-sharing and compliance with tagging standards as a non-negotiable condition of access to public resources—whether the resources are fish stocks and mineral deposits or funds for coastal management or for research.

Capitalising on the Decade of Ocean Science for Sustainable Development, UNESCO’s Intergovernmental Oceanographic Commission (IOC) can establish global standards for metadata, query and data tagging that allow existing datasets to be connected and automatically accessed, as well as sensor positioning and interoperability[473]. Governments, industry and research institutions can use these standards to make their data broadly available in a global federated data network. New partnerships with cloud service providers (such as NOAA’s partnership with Amazon Web Service) should be formed to create open-access data lakes.

In addition, governments can prioritise technology-forcing regulations that target real-time monitoring of fishing, seafood imports, shipping emissions, mineral development, coastal development and pollution and that create public accountability. In the case of fisheries, mandates for vessel-based electronic monitoring, for example, could speed the translation of existing artificial intelligence expertise to ocean management.

The private sector plays a huge role. Many new companies and privately funded initiatives, such as Planet, the Ocean Data Foundation, the Center for the Fourth Industrial Revolution for the Ocean, OceanX and Schmidt Marine Technology Partners, are generating new ocean data and/or providing them free of cost to researchers. Knowledge services can pay for data networks. Already, ocean and climate data are being used as the basis for complex insurance decisions, targeted weather forecasts for precision agriculture and other lucrative knowledge products. Growing corporate interest in traceability across the value chain spawns new solutions, such as the recently launched blockchain platform OpenSC. Tech innovators partnering with NGOs and big seafood companies can extend that capability to small-scale fisheries.

Box 3.1. Key Triggers to Unleash the Ocean Data Potential

- Capitalise on the UN Decade of Ocean Science for Sustainable Development to create a global data network that provides broad and automated access to ocean data.
- Liberate ocean data. Enabled by federated networks, data holders should establish a new default—that ocean data are broadly available to other users unless there are compelling security, proprietary or other interests.
- Create an 'Internet of Things' for the ocean. Coordinated efforts by industry, researchers and governments can create advanced sensor networks that provide high-resolution, real-time information about the ocean to anyone who needs it.
- Automate ocean management based on near real-time data on ocean conditions and resource use.
- Create incentives for innovation. Existing markets do not incentivise many of the technological innovations needed for ocean stewardship and research. Governments and companies can change that.
- Mobilise capital for technologies for underserved markets. Many markets for ocean technologies do not offer commercial returns. Innovative financial instruments are needed that can leverage the expectations and risk tolerances of different investors.

Source: Leape, J., M. Abbott, H. Sakaguchi et al. 2020. "Technology, Data and New Models for Sustainably Managing Ocean Resources." Washington, DC: World Resources Institute. www.oceanpanel.org/Technology-data-and-new-models-for-sustainably-managing-ocean-resources.

Finally, governments, researchers and the private sector need to work together[474]. Jointly developed technology standards are essential to create a fertile ecosystem for innovation. FAO's Port State Measures Agreement, for example, creates new requirements for port monitoring and control that are applied globally and that will require technological innovation in data collection and sharing[475]. In addition, the sectors can collaborate to lower data storage costs. For a summary of these points, see Box 3.1.

Goal-oriented ocean planning: Why does ocean planning matter so much, why is it not mainstreamed yet and how can it be generalised?

Why is it important?

The literally 'free for all' model of ocean use cannot continue. Unrestricted, open-access fisheries almost invariably fail[476]; uncoordinated ocean development creates operational inefficiencies and use conflicts (with attendant litigation and regulatory delays); and unrestricted industrial, nutrient and carbon-related pollution is changing the fundamental ocean chemistry and affecting its biology. More systematic, equitable management is needed for the ocean's resources (principally food and energy), services (weather modulation, carbon sequestration, recreation) and certainly its absorption of externalities (heat and pollution). The current standards and practices of oceanic use planning, accountability, transparency and legal rights and protections remain a century or more behind their terrestrial equivalents. A fresh look at these practices is necessary, shaped by three major systemic objectives:

- **Efficiency and safety.** The different sectors of the ocean economy, such as food, energy and tourism, as well as carbon sequestration and coastal protection, are often symbiotic and have much to gain from being planned as an integrated whole. For example, offshore renewable energy production, the production of non-carbon shipping fuels (ammonium, hydrogen) and large-scale maritime operations all are operationally linked. They could generate significant efficiency gains and avoid impeding on fishing grounds and shipping lanes if carefully integrated with onshore grids and energy markets, and potentially co-located with offshore tourism sites and platforms. Seaweed, finfish and bivalves farms could be co-located (or integrated) to benefit to each other, reduce waste and synergise capital expenditure and operating costs (e.g. boats).
- **Reliable and defensible resource and access rights**. Resource owners, lessees and access holders need secure titling and reliable and effective legal recourse against polluters, trespassers and other

violators. Coastal communities and small-scale fishers need inclusive and equitable access to resources, and recognition of their rights and tenure (food resources, protective reefs and habitats). Investors need reliable, long-term resource access guarantees.

- **Integration and balance of production and protection**. Production and protection need to be in balance, with a strong emphasis on ocean regeneration. This requires careful integration along the dimensions of mitigation offsets (e.g. MPAs in balance with high-use areas), stringent and consistent operating standards (e.g. mariculture standards for containment, disease control, feed composition) and careful facility siting to ensure efficient production while avoiding ecological damage.

Goal-oriented ocean planning is central to these objectives. Three main concepts are usually mentioned when talking about ocean planning: ecosystem-based management, marine spatial planning and integrated ocean management—see Box 3.2 below.

Yet if ocean planning should always be science-based, there is no ‘one-size-fits-all’: an efficient planning process has to be guided by science but tailored to the local parameters, needs and players involved. Some countries have, at least partially, developed and implemented ocean planning and have gone through the testing, failing, learning and adaptation stages. Sharing this variety of experiences internationally would be extremely helpful to nations with less experience. Platforms could be expanded for this purpose. The IOC-UNESCO Marine Spatial Programme, for example, is already ‘documenting marine spatial planning initiatives around the world, identifying good practices of marine spatial planning, collecting references and literature on marine spatial planning and building capacity through training marine spatial planning professionals’[477].

The planning concept should also recognise the social considerations inherent in a transition towards new or more sustainable sectors. Indeed, the Just Transition Centre states that ‘transparent planning that includes just transition measures will prevent fear, opposition and inter-community and generational conflict’[478]. Inspiration for such national strategies or planning

Box 3.2. Ecosystem-Based Management, Marine Spatial Planning or Integrated Ocean Management?

Ecosystem-based management: Management of natural resources that focuses on the health and productivity of a specific ecosystem, a group of ecosystems or selected natural assets as the nucleus of management.

Marine spatial planning: Identifies what spaces of the ocean are appropriate for different uses or activities in order to reduce conflicts and to achieve ecological, economic and social objectives. Usually associated with zoning.

Integrated ocean management: A holistic, integrated, knowledge- and ecosystem-based approach that considers multiple uses and pressures, reconciling competing uses, with the objective of ensuring the sustainability of marine ecosystems.

The three approaches: similarities and differences:

Similar and overlapping in many ways, all three are holistic approaches to human use of the ocean, based on well-defined ocean areas or ecosystems.

The difference is in the main ‘angle’ taken by each of these three approaches: integrated ocean management is rooted in ‘management’ thinking (processes, institutions); ecosystem-based management in ecosystem thinking (interactions between humans and ecosystems); marine spatial planning in analysis instruments such as geographic information systems and zoning.

Sources: Domínguez-Tejo, E., G. Metternicht, E. Johnston and L. Hedge. 2016. “Marine Spatial Planning Advancing the Ecosystem-Based Approach to Coastal Zone Management: A Review.” Marine Policy 72 (October): 115–30. doi:10.1016/j.marpol.2016.06.023; Charles, A., S.J. Evers and A.L. Shriver. 2016. Challenging New Frontiers in the Global Seafood Sector: Proceedings of the Eighteenth Biennial Conference of the International Institute of Fisheries Economics and Trade. Aberdeen, Scotland: International Institute of Fisheries Economics and Trade.

regarding jobs transition can be found in Canada's 'Just Transition Task Force', which was established to support workers who would be affected by the national target of phasing out coal-fired electricity by 2030. This task force is working closely with labour organisations and communities to ensure a just transition plan for Canadian coal power workers and communities[479].

What is preventing (faster) change?

Most of the world's ocean remains largely unplanned and poorly managed for a number of reasons:

- **Planning backlash.** Opposition to ocean master planning is often fierce. It can come in certain regions from the offshore oil and gas sector, in others from commercial fisheries (while the shipping industry is often supportive because of its focus on safe and reliably protected shipping lanes). The opposition is typically concerned that ocean spatial planning is not about rational planning and conflict avoidance but instead a Trojan horse for conservationists seeking new legal tools to pursue a perceived anti-business agenda.
- **Opposition to access control.** Today, titled access happens routinely in the form of extractive leases (e.g. oil and gas platforms and deep-sea mining) and foreign fishing fleet access rights to national waters. While some fishing rights have been in place for decades, in recent years, fishery access rights have been conferred on only 200 fisheries and coastal communities (e.g. 'individual trading quotas' and 'territorial use rights')[480]. Opposition to ocean access rights can be strong from all points on the political spectrum. Some worry about monopolisation or 'corporatisation' of the ocean by the wealthy and well connected, to the exclusion of traditional user groups. Commercial fishing industries are wary of ever-expanding exclusions of their fleets. Coastal inhabitants and competitors often fiercely contest lease sales for near-shore energy and mariculture operations. Legal provisions guaranteeing free ocean-access provisions are on the books in many countries, and certainly enshrined on the high seas through the UN Convention on the Law of the Sea (UNCLOS).
- **Access to data.** Knowledge of the ecosystem is the foundation of integrated ocean management: the biology (fish stocks, migrating patterns, invasive species, primary productivity, etc.), the chemistry (acidity, temperature, nutrients), the physics (currents, waves), the human activity (fisheries, aquaculture, shipping routes, etc.) and the existing regulations and zoning (especially in basins shared by multiple countries). Norway—which has used integrated ocean management for years—is one of the highest spenders in the world, in absolute terms, on marine science. But many countries do not have sufficient scientific capacity or baseline data to provide the knowledge foundation required. The 2017 *Global Ocean Science Report* demonstrated that many countries lack fundamental scientific capacity to underpin their efforts at ocean governance[481].
- **Unfit top-down planning processes.** Top-down planning processes tend to be inefficient. For instance, 265 separate knowledge products concerning ocean management have been produced over five years of a major coral conservation program in Asia—position papers, books, training manuals, field guidance manuals and the like. A recent survey revealed that 54 percent of program participants never or rarely used these knowledge products, and only 20 percent frequently or often used them[482]. On the contrary, in some SIDS, participatory approaches have been very effective at the local level for all phases of the MPA process (MPA planning, implementation, monitoring and evaluation, feedback, adaptation of management plan, etc.)[483].

What are the opportunities for action to overcome these barriers?

Many countries have started to create marine spatial plans (MSPs), a fair number of countries have implemented MSPs in parts of their EEZ, but very few have implemented MSPs for the whole of their EEZ.

A national mandate for an EEZ-wide (and eventually international high seas) ocean planning process can explicitly signal the end of damaging 'free for all' use practices. At its core, this process needs to show how the agendas of ecosystem health, food and energy security, local prosperity and coastal protection can fully re-enforce each other—and what form this takes in explicit spatial, regulatory and operational terms. The process needs to find the spatial balance between production and protection zones (see Section 3.2, point D, 'Ocean restoration and protection'), between the requirements of different ocean users and between the needs of the ocean and the needs of the coast and its people. It needs to provide inclusive, equitable access and recognition for local communities, such as access to traditional fishing grounds, protection of cultural sites, preservation of viewsheds and so on[484].

The development of an ocean plan covering 100 percent of the ocean areas under national jurisdiction

Box 3.3. Major Components of Integrated Ocean Planning and Management

- At the country level, establish comprehensive integrated marine spatial plans for 100 percent of the areas under national jurisdiction. The process (science-based, inclusive, participatory, adapted to local context) is as important as the plan itself.
- Ensure continued funding and capacity for the ongoing implementation of ocean management plans.
- Develop sustainable ocean economic zones as spatially defined 'laboratories' for fully managed areas comprising various sectors, multi-sectoral projects and fully protected areas.
- Develop an international platform to develop and share best practice principles and guidelines for sustainable planning (which could be done by leveraging the ongoing IOC-UNESCO Marine Spatial Programme).

is a time-consuming exercise of broad shareholder participation and shared exploration. This long process is crucial, however, since, apart from economic use considerations, thorough (and often costly) public stakeholder consultations to address gender, equity and distributional issues should be held (see 'Unfit top-down planning processes' above). The development of a protected ocean area plan for the coast of California, for example, required hundreds of community meetings. The interests of shippers, ports, fishers, wind developers, coastal cities, scientists, the navy, local security forces, farmers, water users and so on need to be heard, respected and integrated. This can take two to three years. Once a plan is established, its ongoing implementation requires continued funding.

In the shorter term, the benefits of planning can be demonstrated on a smaller scale. This report champions the idea of smaller 'sustainable ocean economic zones' (SOEZs)—ocean areas which serve as testbeds for a new breed of fully sustainable and regenerative ocean projects (such as multi-trophic farms, renewable energy and the like; see Section 3.3). These SOEZs can catalyse development of an integrated, sustainable ocean economy plan encompassing the entire EEZ or areas under national jurisdiction. For a summary of these points, see Box 3.3.

Innovative finance and de-risking: Why is finance pivotal, and how can more money be mobilised towards a sustainable ocean economy?

Why is it important?

The ocean economy is currently greatly underinvested (even among impact and blended finance investors, SDG 14—'the ocean SDG'—receives the smallest share of them all[485]). Over the 2013–18 period, an average of US$1.5 billion of official development assistance (ODA) a year was allocated in support of the sustainable ocean economy, representing less than 1 percent of global ODA[486]. The finance available for biodiversity and/or conservation is significantly below its need[487]. It has been estimated that currently only about 0.002 percent of global GDP is invested in the conservation and sustainable use of ocean biodiversity, and that about four times the current level of investment is required to meet conservation needs[488].

A growing, sustainable ocean economy needs funding from sources ranging from philanthropy to market-rate investment.

- **Financing innovation**. Many of the sustainable ocean technologies of the future require further commercialisation. This includes floating offshore wind, large offshore multi-trophic mariculture, alternative feed for mariculture, carbon-financed restoration and coastal protection and production of non-carbon shipping fuels. The linkage and symbiosis of these sectors will require considerable development and experimentation. Public finance and subsidies are essential components of the 'industrial strategy' required, as demonstrated exhaustively on land. Demonstration projects are needed to develop 'proof of concept' that can convince institutional investors to engage at scale.

- **Financing infrastructure**. The infrastructural support required is not uniformly in place. This includes offtake and grid access points for offshore energy; energy supply for offshore mariculture; port investments required for the management of sustainable fisheries; marine safety and rescue.
- **Financing the transition**. Transition costs may require public support. This can include investments in worker retraining; consumer awareness campaigns; and much more extensive programs to 'buy down' future (unpriced) costs, such as coastal erosion, expanding dead zones, pollution on beaches and so on. In the context of fisheries, the transition implies a deep reduction of capacity and fishing effort to help rebuild stocks before they are fished (sustainably) again. One study has estimated that the total amount governments need to invest to rebuild world fisheries ranges between $130 billion and $292 billion in present value, cost to be spread over several years and among countries[489].

What is preventing (faster) change?

Six main barriers are preventing more financial flows from entering the sustainable ocean economy space:

- **The investable pipeline for a sustainable ocean economy is not evident.** Investment-grade projects are currently limited and/or hard to find. A survey commissioned in 2020 by Credit Suisse shows that '[l]ack of investment-grade projects/firms at scale' and '[n]ot enough internal expertise' are the two main barriers identified by investors (*n* = 249) to greater investment in a sustainable ocean economy[490]. Examples of new parametric insurance schemes (e.g. coral reefs insurance) are promising but still mostly confined to the pilot stage. Recent solutions have been developed to mobilise commercial impact finance into marine protected areas through long-term management lease of the MPAs. The scalability of the approach must nonetheless be demonstrated. In the short term, the number of MPAs with tangible business models that include monitoring of abuses and enforcement of sanctions seems limited.
- **Incentives are either not in place or are out of place**. In the absence of national 'ocean industrial strategies', harmful subsidies have been allowed to distort the current ocean economy, typically promoting the expansion of fishery capacity (mostly directed to large-scale industrial fishing fleets[491]) and the extraction of oil and gas. At the same time, constructive subsidies supporting sustainable ocean enterprises—such as demand guarantees, low-cost infrastructure support and access to low-cost capital—have lagged far behind. In addition, the risks associated with unsustainable management of the ocean have been inadequately considered: most externalities (e.g. climate change, pollution, violation of human rights) are today not priced by the market and allow unsustainable businesses to thrive.
- **It is generally risky to invest in the ocean space**. In many cases, key technologies are available but not yet fully tested in the cauldron of open ocean conditions, intensifying storms, increasing acidification and shifting currents. Onshore competition, such as from onshore wind, freshwater aquaculture and alternative proteins, is a source of considerable uncertainty. Lastly, potential sources of use conflict abound, with the attendant regulatory risks and delays. Sovereign wealth funds have so far not lined up behind 'ocean industrial strategies' in the same way they have done on land. Institutional investors still lack some of the knowledge and capacity to invest in new ocean technologies. In the absence of sovereign guarantees and institutional growth capital, development finance institutions and multilateral development banks also have largely stayed away. Blue bonds have grown but are complex to replicate and have narrow applications.
- **Impact of (sustainable) finance in the ocean space is not well measured.** The positive impact of sustainable investments on economic, social and environmental dimensions is not well understood and measured. For instance, a recent analysis has taken stock of existing impact evaluation studies relevant to the conservation and sustainable use of both terrestrial and marine ecosystems. It finds that of the nearly 80 impact evaluation studies identified, only 3 were relevant to ocean issues (mainly MPAs)[492].
- **Governments don't invest enough in the 'transition'.** Fishing companies and fishers are likely to lose profits and wages (in the short to medium term) if fishing efforts are reduced so fish stocks can rebuild[493]. Several studies have forecast an attractive economic return for rebuilding fish stocks and fishing them sustainably, but governments may need to invest extra resources in the short term to mitigate transition challenges. Policymakers 'often perceive this rebuilding cost to

be too expensive in the short-term'[494]. Consequently, policymakers usually avoid taking the actions necessary to start the transition[495] (e.g. repurposing subsidies, supporting fishers in a transition to other livelihoods, providing financial compensation where appropriate, etc.). Recently, NGOs such as the Blue National Capital Financing Facility (part of the International Union for Conservation of Nature) have been advancing this agenda.

- **The ocean and finance communities lack shared language.** One of the challenges for creating investable pipelines in some ocean sectors (nature-based solutions, wild-caught fisheries) is that these communities cannot effectively communicate their needs in ways that financiers can easily understand[496]; there is particular misalignment in the generation of metrics from the conservation sector that can produce data applicable to financial decision-making. The *Ocean Finance Handbook*, recently published by the World Economic Forum, is helping to address this barrier[497].

What are the opportunities for action to overcome these barriers?

In a more investor-friendly world with secured resource access rights, infrastructure and offtake guarantees, well-established operational standards and regulatory frameworks, and availability of sovereign wealth funds as lead investors, the capital markets are likely to open for ocean investments.

The following strategies can accelerate change:

- **Provide investment conditions required by sovereign and institutional investors.** Experience with emerging industries on land has shown that sovereign wealth funds typically play a central role in providing a debt capital pool for nationally prioritised and strategic emerging industries. In many cases, these funds guarantee matched debt or equity funding from a coalition of development finance institutions. This concentrated and coordinated approach has the dual benefits of (1) systematically de-risking the investment in unfamiliar industries and (2) creating a pool of domain knowledge and capacity ahead of the market. Both benefits are essential in attracting investments from the institutional finance community, which remains relatively unfamiliar with many aspects of the sustainable ocean realm. Investment by sovereign wealth funds and development finance institutions will require appropriate national commitments. In many cases, they will require that sustainable ocean development be nationally prioritised and formalised in an ocean-industrial strategy. In some cases, this strategy can be trialled and launched in special ocean economic zones dedicated to the development of specific conforming ocean industries within strict selection and operating standards.

- **Boost and diversify the investment pipeline**. National technology innovation programs, typically using a mix of research support, grants and below-market-rate investments in prototypes and early-stage application, can significantly accelerate commercialisation (e.g. Norway's support of next-generation offshore aquaculture and the European Union's support of offshore wind generation). With appropriate titling in effect (e.g. conservation and restoration leases) and the reduction of transaction costs[498], carbon and offset finance could become a major investment vehicle for large-scale restoration and conservation projects. Incubation and acceleration programs, partnerships with schools, universities or corporations can all help accelerate ocean innovation. The investment pipeline also needs to be pushed to include more women, Indigenous people and minorities. For instance, the Impact Investment Exchange (IIX) Sustainability Bonds—developed and implemented by the IIX and IIX Foundation USA—explicitly targets the inclusion of women in economic activities.

- **Improve investment conditions in a sustainable ocean economy.** Public support in the form of margin enhancement (e.g. low-cost infrastructure costs, feed-in tariffs, subsidies) and risk reduction (e.g. regulatory certainty, insurance, offtake and demand guarantees) is also often required, in particular for capital-intensive offshore developments such as wind energy and large-scale mariculture. Significant oversight is necessary, however, to ensure that public support is catalytic (i.e. designed to accelerate commercialisation and innovation) and does not devolve into permanent and ultimately unproductive subsidies. Environmental and sustainability standards can also be advanced by applying stringent criteria in public procurement auctions for products and services, as in the CO_2 emission criteria for public ferries in Norway, which make later electric ferry projects economically attractive.

- **Develop blended finance solutions to de-risk private capital investment**. The concept of blended finance is to use public or philanthropic money to reduce investor risk or improve returns. This is one

Box 3.4. Key Triggers to Unlock Finance for a Sustainable Ocean Economy

- Provide investment conditions required by sovereign and institutional investors.
- Boost and diversify the investment pipeline.
- Improve investment conditions in a sustainable ocean economy.
- Develop blended finance solutions to de-risk private capital investment.
- Repurpose harmful subsidies to more equitable and sustainable uses.
- Map financing flows.

way to unlock commercial capital for a sustainable ocean economy, especially in higher-risk countries or for new technologies. Using a tranched fund structure to 'blend' capital with different risk appetites and impact mandates is one of the most common forms of blended finance in the ocean space (e.g. Althelia's $100 million Sustainable Ocean Fund, Rare's $30 million Meloy Fund, the California Fisheries Fund or Climate Fund Manager's upcoming 'Climate Investor Two'), but many other structures can also mobilise commercial capital for sustainable ocean assets. More case studies and an explanation of different blended finance structures can be found in the reports published by the Blended Finance Taskforce[499] and the Friends of the Ocean Action[500].

- **Repurpose harmful subsidies to more equitable and sustainable uses.** Multilateral forums, such as APEC, the G20 and the G7, have called repeatedly for phasing out inefficient fuel subsidies and distortive support measures[501]. This momentum for reform can be channelled into better policies for the ocean economy, for instance in rebuilding fisheries (see 'Governments don't invest enough in the "transition"' point above). The World Trade Organization (WTO) missed its own December 2019 deadline to reach an agreement to 'prohibit certain forms of fisheries subsidies that contribute to overcapacity and overfishing and eliminate subsidies that contribute to illegal, unreported, and unregulated fishing'. A new deadline has now been set (December 2020) for the WTO ministerial meeting. This is an essential milestone.
- **Map financing flows**. The OECD *Sustainable Ocean for All* report presents the first-ever estimates of ocean-relevant official development assistance, covering the (sustainable) ocean economy as well as land-based activities with impacts on the ocean. This is a great first step towards much more comprehensive monitoring of public, private, domestic and international financial flows into the ocean economy, which is urgently needed. For a summary of these points, see Box 3.4.

Stopping land-based pollution: How does the current political and economic constellation make it nearly impossible to stop ocean pollution? How could this be changed, and where do we start?

Why is it important?

Ocean pollution is largely an externality of the terrestrial economy. Plastics, nutrients (primarily nitrogen and phosphate), pesticides and parasiticides, antibiotics and pharmaceuticals, industrial chemicals including persistent organic pollutants, oil and gas, medical waste, e-waste and disaster debris are diverted to the ocean with very little financial consequence for the polluter. But ocean dilution is no longer the solution to pollution—the consequences, as described in Chapter 1, are significant and deeply concerning.

Marine plastic litter has received the most attention recently. Plastic pollution is ubiquitous (9–14 million metric tonnes leaking into the ocean every year[502]) and iconic (animals starving from plastic ingestion, strangulation, littered beaches). The root cause is straightforward: waste management infrastructure in industrialising countries (especially in Asia and Africa) is lagging far behind their rapidly rising consumption of plastic. With few consumer products designed for recyclability (just 2 percent of plastic packaging is made from former plastic[503]), waste collection is largely unprofitable and plastic 'leakage' into the environment is correspondingly high.

Ocean 'dead zones' are also proliferating, as are toxic algal blooms. Around 700 sites worldwide are now affected by low oxygen conditions—up from only 45 in the 1960s[504]. These result from a combination of climate change (warmer waters absorb less oxygen) and nutrient pollution from fertiliser, sewage, animal and aquaculture waste, which causes excessive growth of algae, leading to oxygen depletion when later decomposed by bacteria[505].

The impact of industrial, pesticide and oil-spill pollutants on the marine food web is also well documented. Bio-accumulation of mercury in food fish, for example, is so high that health organisations are issuing safe human consumption guidelines for many predator species, including tuna, billfish and sharks[506]. Virtually every pollutant present on land is also present in the ocean at detectable levels, with compounding and significant impacts on ecosystem health. Oil spills such as the Deepwater Horizon accident in the Gulf of Mexico have had devastating long-term impacts on the ocean floor and coastal habitats[507].

What is preventing (faster) change?

In general, addressing the ocean pollution challenge has been complicated by the difficulties of attribution (many pollutants are non-point-source) and by the overwhelming asymmetry of the situation: when heavily protected terrestrial private interests clash with the interest of a weakly defended common pool resource like the ocean, the ocean loses.

Reform of the plastic economy is specifically impeded by three principal factors:

- **Price differential between virgin and recycled products.** The current price of virgin plastic resin is historically low, making recycling of most polymers unprofitable without subsidies. An adjustment of virgin cost, through voluntary industry initiative or imposed through policy, would (1) launch significant entrepreneurial activity in the waste management and collection sector, (2) make collection of plastic waste more profitable and (3) provide a major incentive for consumer brands to include recyclability in their packaging product design.
- **High capital and operating costs of waste management infrastructure.** Introducing modern plastic waste collection infrastructure into the developing world will require capital expenditures of billions of U.S. dollars per year[508] (with operating costs several multiples higher). The public sector in these countries is going to rely on the 'extended producer responsibility' schemes used by developed countries for sources of finance. However, translating these schemes into the infrastructure, governance and legal frameworks of developing or industrialising countries is challenging. In addition, the costs associated with the development of new technologies (e.g. chemical recycling) and the transition towards plastic substitutes are considerable, and it is not clear how those costs can be equitably allocated among industry players.
- **Lack of transparency.** The flow of recyclable and non-recyclable plastics through the value chain, from the resin producer through the brands to the waste manager, is currently largely undocumented. It is thus difficult for a producer or brand to differentiate its 'plastic performance', and to be rewarded by the market as a leader and good faith actor in the fight against ocean plastic. On the opposite side of the coin, it is nearly impossible for civil society to hold responsible companies which are side-stepping the ocean plastic problem.

Pesticide, nutrient and industrial pollution control is largely a political challenge. Agricultural and industrial production has long benefitted from the ocean's dilution of excess nutrients, pesticides and industrial toxins, and the resulting rents tend to be well protected legally, politically and culturally. In the United States, for example, it is very difficult to pursue legal action against non-point-source polluters. Environmental enforcement budgets are constantly under attack.

What are the opportunities for action to overcome these barriers?

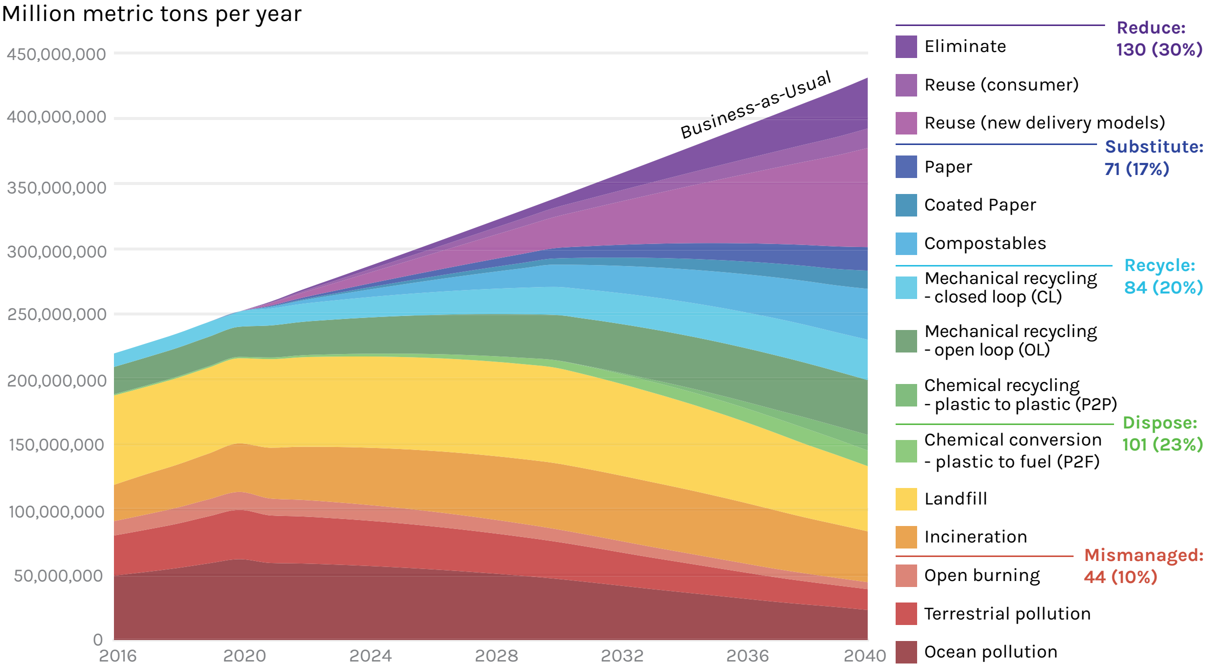
A growing number of governments and industries are announcing new measures and commitments (e.g. plastic bag bans). However, a recent study quantified that such efforts will barely make a difference: by 2040, current government and industry commitments are likely to reduce annual plastic leakage into the ocean by only 7 percent relative to a BAU scenario[509].

There is no silver bullet solution to ocean plastics pollution. A more diverse portfolio of more ambitious solutions should be deployed, including reduction of unnecessary plastics, substitution with other materials, recycling (mechanical and chemical) and safe disposal (see Figure 3.6).

Many technical solutions are available today to governments and industry, but they could be accelerated by three major reforms:

- **Recalibrate the economic advantage of virgin plastic** to stimulate the demand and competitiveness of recycled materials. This can be done in multiple ways; for instance, through the global adoption of extended producer responsibility (EPR) schemes or the increased taxation of virgin production.
- **Invest massively in waste collection and recycling technology and infrastructure**. The highest priority in the short term is collection infrastructure in the developing world—collection rates need to stay ahead of recycling capacity to ensure reliable feedstock flows.

Figure 3.6. Plastic Leakage into the Ocean Can Be Reduced Significantly Only If All Solutions Are Implemented Concurrently, Ambitiously and Starting Immediately



Note: The 'wedges' figure shows the share of treatment options for the plastic that enters the system over time under the System Change scenario. Any plastic that enters the system has a single fate, or a single 'wedge'. The numbers include macroplastic and microplastic.

Source: Lau, W.W.Y., Y. Shiran, R.M. Bailey, E. Cook, M.R. Stuchtey, J. Koskella, C.A. Velis et al. 2020. "Evaluating Scenarios toward Zero Plastic Pollution." Science, July. doi:10.1126/science.aba9475.

- **Bring transparency and accountability to the flow of plastic polymers through the value chain.** The performance of companies selling plastic products needs to be fully transparent over time (in terms of shifting to more recycled content, recyclable product design and plastic substitutes).

These measures are within reach. The management of plastic waste in the developing world will not remain as an unpriced externality much longer—virgin plastic taxation schemes are under discussion in many countries. Plastic producers and brands may choose to pre-empt taxation with alternative, industry-led EPR initiatives and funding mechanisms. Recent announcements by industry, including the plastic industry's $1.25 billion Alliance to End Plastic Waste and Nestle's $2.1 billion commitment to tackle plastic waste, are not likely to be the only major commitments forthcoming soon.

In the fight against nutrient pollution, dead zones and toxic algal blooms, the sustainable ocean economy is in a direct confrontation with land-based agricultural interests. The technologies for precise applications, runoff controls and soil regeneration are well established[510] and could drastically reduce the need for input on crops, but they are not mainstreamed yet on a global scale. As the sustainable ocean economy develops further, its economic interests will be more fully represented in the political and legal realm—and it is doubtful that the periodic death of entire coastal ecosystems will remain uncontested for very long.

- It would, of course, be far preferable to avoid this inevitable confrontation by proactively requiring precision fertilisation, low-input farming and regenerative agriculture, especially along major rivers. However, the current political economy will likely require ocean interests to assert their interests in a formal way for this to occur. For a summary of these points, see Box 3.5.

Box 3.5. Key Triggers to Reduce Land-Based Pollution in a Sustainable Ocean Economy

- Recalibrate the economic advantage of virgin plastic.
- Invest massively in waste collection and recycling technology and infrastructure.
- Bring transparency and accountability to the flow of plastic polymers through the value chain.
- Require the adoption of precision agriculture to avoid nutrient runoff.

Upgrading ocean accounting: How do current metrics and public accounting conventions (gross value added, gross domestic product) drive the wrong priorities, what can be changed, and how can we start the change today?

Why is it important?

Ocean macroeconomics has long focused on 'outputs', typically expressed in terms of GDP metrics. Microeconomic metrics—market size, growth rates, returns—have been similarly output-focused. But these metrics are flawed—they measure the flow of capital but ignore the 'stocks', the value of the manufactured and natural capital involved in the production process. They also don't measure the importance of human capital (knowledge, aptitude, education and skills). For decades, world-class economists (Dasgupta, Jorgenson, Kuznets, Nordhaus and Tobin, Solow, Stiglitz, Weitzman, etc.[511]) have warned about the perils of a focus on GDP only, arguing that it ignores the true cost of production and does not put human well-being at the centre of the economic debate: 'Growth is a means to an end, rather than an end in itself'[512].

The broader value of the ocean must be fully accounted for and used in decision-making.

The System of National Accounts (SNA) could document progress along the dimensions of productivity, job creation, food security, regional stability and long-term ecosystem health. A complete set or 'sequence' of national ocean accounts could provide highly insightful information for the sustainable management of the ocean economy. Three key high-level indicators can already provide a much more holistic picture than the use of GDP only to inform policy and ocean-related decisions: ocean product, net change in the ocean balance sheet and ocean income:

- **Ocean product** is the traditional measure of the ocean's output, generally monetised in terms of ocean 'gross domestic product' (GDP) or 'net domestic product' (NDP).
- **Net change in the ocean balance sheet** provides a sustainability indicator. It accounts for the reserves of natural and produced capital in the ocean, as driven by economic activities. Changes in the balance sheet indicate physical and monetary changes to show how wealth and opportunity change through time (adjusted for anticipated price changes).
- **Ocean income** measures benefits to nationals from the ocean, the 'ends' or 'outcomes' of policy. It is generally expressed in terms of net or gross national income (NNI or GNI). Income can include non-monetary types of income, though these are often expressed in monetary equivalents.

What will an ocean account monitoring these three indicators change? Good information is not sufficient to ensure good decisions, but it helps. The development of national accounts has had an impact on inflation and the business cycle, which has generally made the economy more stable and enhanced human well-being[513].

In parallel, it is useful to promote more flexible approaches to natural capital valuation and use in decision-making that can be tested and deployed with less inertia and complexity than with the SNA, with the eventual goal of reconciling these two approaches. Some examples of such alternative methodologies include using payment for ecosystem services schemes that have been used in the United Kingdom[514] and Costa Rica[515], for instance, or the gross ecosystem product (GEP), which is increasingly used by the Chinese government as part of a transformation to inclusive, green growth[516].

What is preventing (faster) change?

Developing national accounts to guide economic development is less daunting than it may seem. Most of the data already exist in national accounts, in government agencies or in scientific databases. The knowledge to build the connections exists, although it is dispersed throughout the government, academic, business and NGO sectors. Many countries already produce 'marine GDP' reports that may be a good starting point.

Several barriers remain:

- **Old habits.** Even in 2020, economic and policy decisions are still mostly based on 19th-century economic paradigms, with rigid definition of economic sectors and metrics, a failure to differentiate sources of income in terms of externalities and no monetisation of natural capital.
- **Siloed data.** Much of the information needed for ocean accounts exists but is siloed in multiple government agencies, as well as in the academic, business and NGO sectors. In a few cases the data are not yet available, for instance, biophysical data needed to quantify natural stocks. Also, the tagging of databases is not standardised, making it difficult to know precisely what's available.
- **Methodology.** Despite the rising momentum behind this new generation of accounting, there is still a need for standardisation and reforms of existing accounting systems and valuation methods, within and across countries.
- **Lack of track record in informing decision-making.** Policy- and decision-makers are lacking demonstrations showing how these indicators actually can inform decisions (and are informing them).

What are the opportunities for action to overcome these barriers?

Four main areas of action could accelerate the development and use of these holistic ocean accounts:

- **Create national ocean accounts.** National statistical offices, in partnership with marine agencies, need to develop a complete sequence of national ocean accounts: product, income, balance sheets and supply and use tables. This should be achievable by 2025. In particular, they need to ensure the compatibility of ocean accounting efforts with international statistical standards and approaches, mainly the System of National Accounts, the System of Environmental Economic Accounting (SEEA), the 10 Fundamental Principles of Official Statistics endorsed by the UN General Assembly in January 2014[517] and other broadly accepted initiatives[518]. Next to these accounts, more flexible approaches to natural capital valuation and use in decision-making can be encouraged (e.g. GEP in China and other examples mentioned above), and alignment should be ensured between these approaches and the ones using national accounts.
- **Develop and use interactive dashboards for ocean account reporting**. Such dashboards allow users to explore the data, aggregate and disaggregate sectors and groups of people, alter the account boundaries and access ethically acceptable disaggregation by digital means. These dashboards would stimulate decision-making based on more holistic information more than GDP only, and they would track national progress over time.
- **Encourage international collaboration and standardisation.** National governments should ensure that their national accountants, economic analysts and marine scientists participate in workshops organised by the UN Statistical Division and associated organisations for developing ocean accounts. This will help to maintain standards and increase credibility. These international organisations need to evolve to provide a degree of third-party verification of accounts coupled with capacity-building assistance.
- **Invest in data architecture and engineering, and build know-how in national statistical offices.** Governments need to invest in data architecture and engineering at levels surpassing global multinational companies. These investments are necessary to connect fine-scale data about the marine environment with detailed economic data in supply-and-use structures and other data structures for national accounting and forecasting the ocean economy. These investments should build on existing Earth observation programs when possible. Investment must also include investments in people. The costs of implementing the ocean accounts—including embedding them in relevant laws, policies and action plans—will likely be far outweighed by the benefits current and future generations gain from sustainable ocean economies. For a summary of these points, see Box 3.6.

Box 3.6. Key Triggers to Develop and Mainstream Ocean Accounts

- Create national ocean accounts covering product, income, balance sheets and supply and use tables.
- Develop and use interactive dashboards for ocean account reporting.
- Encourage international collaboration and standardisation.
- Invest in data architecture and engineering, and build know-how in national statistical offices.

3.2 Five key sectors to be transformed towards a sustainable ocean economy

Sustainable food from the ocean: How can sustainable ocean fishing and farming feed a planet with 10 billion people?

Why is it important?

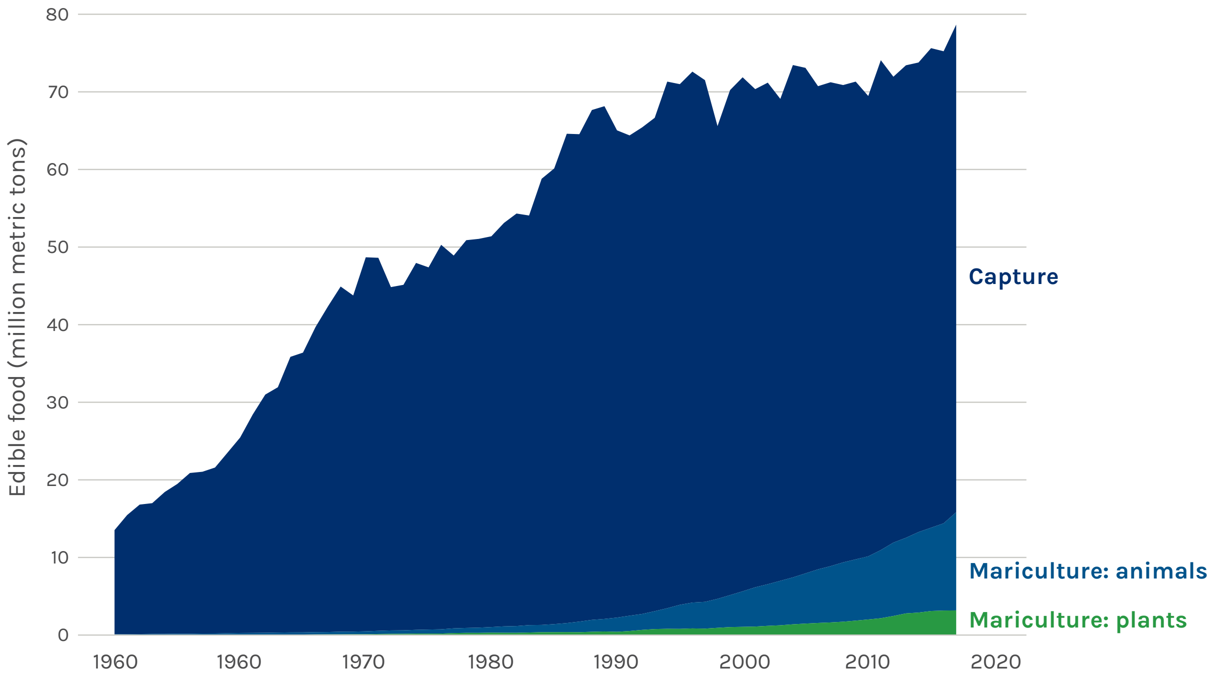
Ocean fish provides about 3.2 billion people with almost 20 percent of their average intake of animal protein[519]. This number is even higher in developing regions such as Indonesia, Sri Lanka and many small island developing states, which derive 50 percent or more of their animal protein from aquatic foods[520]. Ocean food is also a unique source of long-chain omega-3 fatty acids, minerals, calcium, iodine and vitamins[521]. To simplify, food from the ocean can be split into two main sectors: wild-caught fisheries and mariculture—the latter can then be divided into unfed (e.g. seaweed and filter-feeders) and fed mariculture (e.g. finfish and crustaceans). Today the lion's share of ocean food production comes from wild-caught fisheries (in tonnes of edible food equivalent; see Figure 3.7).

The ocean can contribute to sustainable food security for 10 billion people. Ocean animals are more efficient than terrestrial systems in producing protein[522]; their impact on climate change and land use is in general much lower than terrestrial animal proteins (Figure 3.8) and their production is not limited by suitable area available.

By applying realistic demand scenarios to the sustainable seafood supply potential presented in Chapter 2 (six times more seafood than today), a recent paper determined the plausible future equilibrium quantity of food from the sea that could be produced and consumed. This still represents a significant expansion, calculated to represent a 36 to 74 percent production increase compared to today's levels[523].

Yet the current ocean production system is not on track to deliver this production increase in a sustainable way.

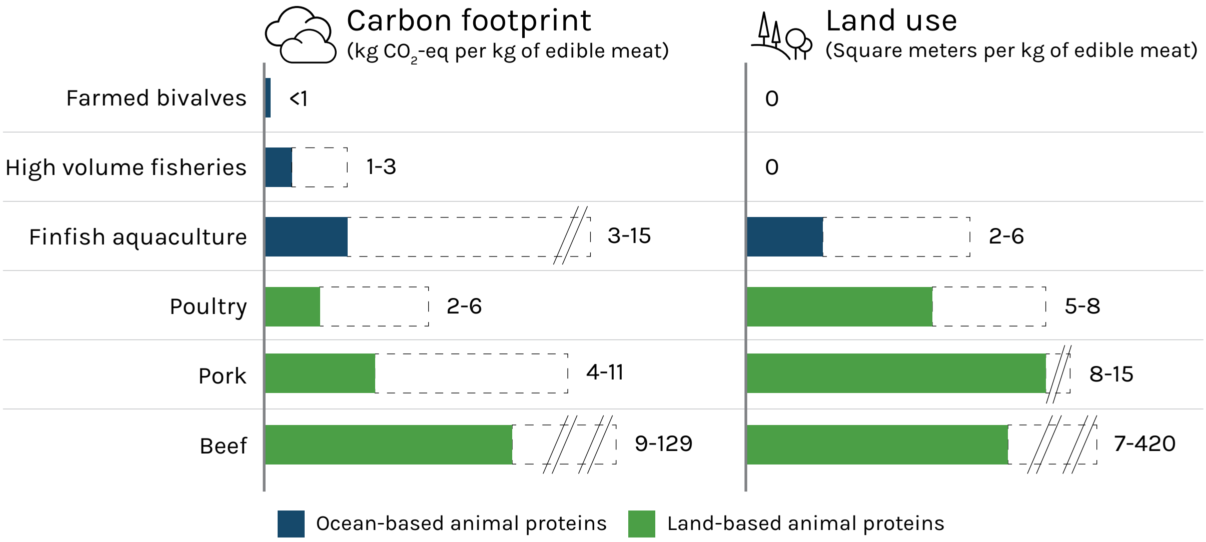
Figure 3.7. Historical Production of Marine Capture Fisheries and Mariculture (Edible Weight)



Note: This figure shows food potential, as it does not take into account historical non-food use.

Sources: Production data are from FAO. 2019. "Fishery and Aquaculture Statistics: Global Production by Production Source, 1950–2017 (FishstatJ)." FAO Fisheries and Aquaculture Department. www.fao.org/fishery/statistics/software/fishstatj/en. Landed quantities are converted into million metric tons of edible food equivalents using conversion values from Edwards, P., W. Zhang, B. Belton and D.C. Little. 2019. "Misunderstandings, Myths and Mantras in Aquaculture: Its Contribution to World Food Supplies Has Been Systematically Over Reported." Marine Policy 106 (August): 103547. https://doi.org/10.1016/j.marpol.2019.103547; and Duarte, C.M., J. Wu, X. Xiao, A. Bruhn and D. Krause-Jensen. 2017. "Can Seaweed Farming Play a Role in Climate Change Mitigation and Adaptation?" Frontiers in Marine Science 4. doi:10.3389/fmars.2017.00100.

Figure 3.8. Land Use and Carbon Implications: Comparison between Ocean-Based and Land-Based Sources of Proteins



Note: This figure shows food potential, as it does not take into account historical non-food use.

Sources: Nijdam, D., G.A. Rood and H. Westhoek. 2012. "The Price of Protein: Review of Land Use and Carbon Footprints from Life Cycle Assessments of Animal Food Products and Their Substitutes." Food Policy 37 (6): 760–70. 10.1016; Filgueira, R., T. Strohmeier and Ø. Strand. 2019. "Regulating Services of Bivalve Molluscs in the Context of the Carbon Cycle and Implications for Ecosystem Valuation." In Goods and Services of Marine Bivalves, edited by A.C. Smaal, J.G. Ferreira, J. Grant, J.K. Petersen and Ø. Strand, 231–51. Cham, Switzerland: Springer International.

FAO estimates that 33 percent of global fish stocks are overfished, and nearly 60 percent exploited at maximum capacity[524]. The wild-caught production has been stagnating in the past three decades at about 80 MMT/yr. of landed weight. Illegal, unreported and unregulated (IUU) fishing remains a major problem, accounting for 11 to 26 MMT of catch and creating financial losses of between $10.0 billion and $23.5 billion per year[525]. Fisheries on the high seas (e.g. tuna, jacks) are subject to multilateral management institutions which have, in the past, frequently not adopted scientific recommendations[526]. In a BAU scenario, 2050 yields could decrease by almost 16 percent to about 67 MMT/yr. because of the cumulated pressures of overfishing, climate change and pollution[527]. Commercial fishing activities also affect fauna like birds, marine mammals and turtles. For example, the World Ocean Assessment states that 'each year, incidental bycatch in longline fisheries is estimated to kill at least 160,000 albatrosses and petrels, mainly in the southern hemisphere. For marine reptiles, a threat assessment scored fishery bycatch as the highest threat across marine turtle subpopulations'[528].

Mariculture has been growing at a stable pace in recent years, around 5.8 percent annually[529], but finfish mariculture is too often associated with unsustainable practices (e.g. fish escapes, local fouling, overuse of antibiotics, disease transfer) and is critically constrained by the need to 'fish wild fish to farm fish'. As a result, many consumers still consider wild-caught fish to be of higher quality than farmed fish.

Finally, the significant amount of food waste in the seafood value chain represents a missed opportunity to boost consumption without increasing production. Indeed, FAO estimates that 35 percent of fish and seafood is wasted, including 8 percent of all fish caught being thrown back into the water (in most cases, these fish are dead, dying or badly damaged)[530]. This waste is equivalent to almost 3 billion Atlantic salmon[531].

The current and BAU production numbers fall far short of the ocean's productive potential. If all stocks were sustainably managed and fishing effort were maximised for profit, yields from wild-caught fisheries could increase to 98 MMT/yr. in 2050. This is an about 20 percent increase from current levels and represents an increase in profit of $53 billion in 2050 (in comparison to BAU)[532]. These gains are dependent on widespread

Box 3.7. Seaweed: The Versatile Ocean Super Crop

Seaweed cultivation is the fastest growing mariculture sector (7 percent per year)[a], already producing over 30 million metric tons (valued at US$4.8 billion)[b]. As a thousand-year-old industry in Asia, it is unsurprising that the largest share of the world's seaweed is produced on the coasts of this continent—China and Indonesia alone produce over 85 percent of global volume[c]. About 10 species are intensively cultivated[d]. Europe and North America are catching up to the benefits of producing this super crop. Through the Pegasus project, for instance, the European Union developed guidelines for the sustainable aquaculture of seaweeds. The project showcased the many benefits of seaweeds. Not only do they not require land or freshwater, but seaweed farms also provide habitat for many marine species, mitigate storm damage, sequester carbon, provide bioremediation services (e.g. degrade or assimilate contaminants as excess nitrogen and phosphorus) and can protect calcifiers from projected ocean acidification[e]. Their uses are similarly broad and promising. Seaweeds are already extensively used in the pharmaceutical and nutraceutical industries, consumed directly as human food (e.g. directly in soups and salads or processed into noodles and seasoning) and food additives, transformed into fertiliser or refined into biofuels. They are being increasingly explored as animal feed (even shown to reduce methane in ruminants by a factor of up to 80 percent in one case, even if more research is needed[f]), or can be a base ingredient for bioplastics[g].

With new seaweed applications being found yearly, and a potential cultivation area of 48 million km^2 (about three times the current area used for growing crops—16 million km^2)[h], seaweeds could become an ever more present sustainable ocean crop in the decades to come—if their farming development is supported by adequate marine spatial planning[i], and if innovations help seaweed-based products to enter new markets.

Sources:

[a] *Dubois, O. 2011. The State of the World's Land and Water Resources for Food and Agriculture: Managing Systems at Risk. London: Earthscan, FAO. https://www.cabdirect.org/cabdirect/abstract/20123051697; Costello et al. 2019. "The Future of Food from the Sea."*

[b] *Barbier, M., B. Charrier, R. Araujo, S.L. Holdt, B. Jacquemin and C. Rebours. 2019. "PEGASUS: Phycomorph European Guidelines for a Sustainable Aquaculture of Seaweeds." Roscoff, France: COST: European Cooperation in Science and Technology. http://www.phycomorph.org/doc/PEGASUS_SUSTAINABLE_SEAWEED_AQUACULTURE_FULL_RECOMMENDATIONS.pdf.*

[c] *Costello, C., L. Cao, S. Gelcich et al. 2019. "The Future of Food from the Sea." Washington, DC: World Resources Institute. https://www.oceanpanel.org/blue-papers/future-food-sea.*

[d] *FishStatJ: Software for Fishery and Aquaculture Statistical Time Series. n.d. Rome: Food and Agriculture Organization of the United Nations, Fisheries and Aquaculture Department.*

[e] *Duarte, C.M., J. Wu, X. Xiao, A. Bruhn and D. Krause-Jensen. 2017. "Can Seaweed Farming Play a Role in Climate Change Mitigation and Adaptation?" Frontiers in Marine Science 4. doi:10.3389/fmars.2017.00100.*

[f] *Mulhollem, J. 2019. "Seaweed Feed Additive Cuts Livestock Methane but Poses Questions." Penn State University, 17 June. https://news.psu.edu/story/578123/2019/06/17/research/seaweed-feed-additive-cuts-livestock-methane-poses-questions.*

[g] *Barbier et al. 2019. "PEGASUS."*

[h] *Dubois. 2011. The State of the World's Land and Water Resources for Food and Agriculture.*

[i] *Duarte et al. 2017. "Can Seaweed Farming Play a Role in Climate Change Mitigation and Adaptation?".*

policy reforms, such as rights-based approaches that incentivise conservation and hold fishing fleets accountable to science-based limits[533].

The mariculture story is even more promising. Finfish mariculture expansion potential is almost unlimited if the feed can be decoupled from fish meal/fish oil (FM/FO)[534]; the biological potential for finfish mariculture production is estimated to be around 15,000 MMT. Unfed mariculture also holds great promise: a study found that the ocean has the potential to produce nearly 768 MMT of bivalves (shell-on weight), and about 60 percent of this production would be profitable at roughly the current price for blue mussels ($1,700/MMT)[535]. Unfed mariculture (e.g. bivalves and seaweed) can also substantially increase nutritious food and feed with a lower impact on the marine environment, and may in some cases enhance wild fisheries by creating artificial habitats. Seaweed production is growing strongly (11 percent annually) from a small base (30 MMT/yr.). Seaweed and macroalgae have the potential to help solve food security issues, act as a form of carbon sequestration, reduce ruminant methane emissions and so on[536] (see Box 3.7). There are few geophysical (48 million km^2 are suitable for cultivation)[537] or technical constraints to doing so[538]. This industry is clearly still in its infancy, with much consumer product development and testing yet to be done.

What are the opportunities for action to accelerate change?

There is no alternative to regulation—and enforcement—in fisheries. Unregulated, 'free access' fisheries almost invariably overfish[539]. Unregulated fleets tend to grow to the point of little or no profit for the individual boat—a point that is ecologically and economically irrational and destructive and which can be driven to absurdity by national subsidies. Ports allowing illegal or untraced seafood to be unloaded without verification are maintaining these destructive practices. The governments of most industrialised nations have addressed this problem with various types of catch restrictions and port controls. With rare exception, stocks have shown a heartening capacity to recover once the pressure is eased.

Reform is impossible without rules to protect the stocks and allow for an efficient, fair and equitable allocation of catch[540]. First and foremost, the commercial right to fish needs to be predicated on a plan to fully restore the target stock within 10 years (or as soon as possible for fish stocks with longer recovery time)[541]. This has been the key feature of the Magnuson-Stevens Fishery Conservation and Management Act, which successfully restored fish stocks and fisheries in the United States (see case study in Section 1.1), and the European Common Fisheries Policy. Second, within the framework of these restoration targets, catches must be restricted to a level that results in the rebuilding of fish stocks, followed by sustainable levels of fishing[542]. Third, the allowable catch must be allocated fairly—to provide food security to artisanal fishing communities and to tie the fortunes of commercial fishers to the health of 'their' stocks[543]. Fourth, the Port State Measures Agreement must be enforced in all ports to close illegal fishing. Finally, the implementation of fully protected MPAs has been demonstrated to generate significant spillover effects that can benefit surrounding fisheries[544]. Such MPAs could be an integral part of a fishery recovery plan for some fisheries. Finally, several technical innovations can help reduce bycatch and lost fishing nets, as well as prevent food loss during fishing and processing. In addition to regulatory changes, the financial community can deploy innovative funding mechanisms to support the transition towards sustainable fisheries (e.g. Meloy Fund, California Fisheries Fund).

The acceleration of sustainable mariculture will require the coordinated intervention of governments and investors, as well as an adjustment of consumer preferences. The Food and Land Use Coalition strongly recommends that governments 'support new feed technologies with clear targets (standardized performance specifications for feed applications), strong incentives (feed efficiency standards), and guaranteed demand (feed standards for government seafood purchases)'[545]. Without compromising strong and independent oversight, governments also need to update regulations so they conform to new best practice technology standards, with low- and multi-trophic operations involving seaweeds and bivalves made a priority. Additionally, governments need to lower the barrier to entry for marine aquaculturists; for example, by providing environmentally stringent, yet easily navigable aquaculture governance frameworks and/or assistance to (excess capacity) fishers who transition to become marine aquaculturists. Finally, governments need to work with farm operators to support the development of model farms which are innovative in terms of feed technology, as well as the integration of different trophic levels (multi-trophic farming), scale, containment, siting and so on.

There is now strong consensus that new feed technology and vaccine delivery systems, as well as improved breeding and genetic selection, have enhanced the investment grade of top-performing mariculture operations[546]. The hope is that continued improvements will lead to a mature and stable industry. Venture and early-stage funding has also entered this space from different sources, including corporate food and feed investors, Silicon Valley firms attracted to the artificial-intelligence and technology aspects of aquaculture, and specialised funds (e.g. Aqua-Spark, a $180 million Dutch aquaculture investment firm). Given the potentially increasing role of aquaculture in the global diet, a strong push will be needed from public funding and official development assistance, ideally led by a consortium of countries with expertise and interest in scaling up. However, appropriate species and local conditions, including market opportunities, differ significantly and will require tailored approaches. Hatcheries and farmers will need to address and preserve genetic diversity while breeding selectively for desirable traits. At the same time, precautions will need to be taken to keep genetically modified species from escaping mariculture operations and altering, or in the worst case replacing, local populations[547].

In both fisheries and mariculture equity issues persist: from forced labour on fishing boats, to lack of recognition and full integration of women in all parts of the fishery and mariculture industry, to unfavourable risk distributions for smallholder mariculture farmers. Solving these equity issues will require the combined force of strong labour legislation, effective enforcement and ensured traceability throughout the supply chain to keep seafood from bad actors out of seafood markets.

Consumers still regard aquaculture finfish as a food category of its own rather than as a potential replacement for poultry, pork and beef—there is little evidence of switching between the two as prices rise and fall[548]. Very little work has been done on predicting how the substitution economics between seafood, plant-based alternative protein and meat will evolve as a function of shifting tastes, prices and processing technologies. The safest bet currently is that additional production of farmed finfish is more likely to meet the protein demand of the new generations than to replace the meat habit of the older ones[549]. Additionally, consumer awareness and resulting demand for sustainably fished or farmed and humanely processed seafood needs to be raised by promoting sustainability labels like those of the Marine Stewardship Council and Aquaculture Stewardship Council.

Research into novel seafood sources, like lab-cultivated seafood, should be supported. Even though lab-cultivated seafood is not grown in the ocean, it still has its genetic roots there. This requires the understanding of cell lines from highly sought-after seafood species. This research should be enabled by easily navigable legislation.

Last but not least, scientific understanding of the implications of harvesting low-trophic species like krill, zooplankton and mesopelagic fish should be increased. The mesopelagic zone, also called the twilight zone, is the layer of water between 200 and 1,000 metres below the ocean surface, just beyond the reach of sunlight[550]. Many animal species live in this zone: zooplankton, crustaceans, squids, gelatinous animals and a multitude of few-inch-long fish usually referred to as mesopelagic fish (the most famous being the bristlemouth fish). The biomass in the twilight zone is not well known, but according to some estimates it could be bigger than the rest of the ocean biomass combined. Many mesopelagic organisms also travel from and to the surface daily, playing an important role in the broader ocean food chain and carbon flux exchanges between the atmosphere and the deep sea. In recent decades, there has been increasing interest in investigating the commercial fisheries catch potential of this immense biomass, for instance, to be used as fish meal or fish oil for aquaculture. However, until reliable stock assessments, and the impact of their harvest on the ocean's food web and the carbon cycle, are understood, a precautionary approach should be followed. The Woods Hole Oceanographic Institution, for instance, is funding a $35 million research project to answer the following questions[551]:

- What species live in the twilight zone, and in what quantities?
- How long do twilight-zone organisms live? How quickly do they grow? At what age do they reproduce?
- To what extent do large ocean predators such as whales and tuna depend on twilight-zone organisms as a source of food?
- How much carbon do twilight-zone animals transfer to the deep ocean through their daily migration? How much carbon sinks out of the twilight zone into deeper waters as marine snow and in other forms?

In Europe, the Ecologically and Economically Sustainable Mesopelagic Fisheries (MEESO) project involves 20 European research centres and universities pursuing similar research on mesopelagic fish[552]. For a summary of these points, see Box 3.8.

Box 3.8. Key Triggers to Revolutionise Food from the Ocean

- Increase official development assistance for fisheries management capacity.
- Artisanal fisheries: Ensure inclusive and equitable access rights to local, well-managed fish stocks.
- Align economic interests and stock health of industrial and small-scale commercial fisheries through capacity and granting of access rights; impose science-based mortality controls in line with sustainability principles for each commercial stock.
- Create climate-smart fisheries and mariculture management structures that plan for, and can adapt to, changing oceanographic conditions under climate change.
- Integrate technologies available for highly adaptive fishery management, new fleet control and tracking technologies, and seamless chain of custody tracking and registration of rights, ownership, titles, obligations and so on through new ledger and registration technologies.
- Repurpose subsidisation of fishing capacity for fleet control infrastructure, port improvements (e.g. enforcement of the Agreement on Port State Measures, icing facilities) or financing of the cost of fish stock recovery.
- Ban damaging fishing, such as destructive bottom-trawling and blast fishing, and incentivise fishing gear and techniques that minimise bycatch of non-target species.
- Develop the required modalities and business models to support fishers in their transition (to be developed by insurers and investors, including through sovereign or outward direct investment, development finance institutions and multilateral development banks).
- Streamline mariculture permitting through easily navigable permitting processes that include environmentally rigorous permitting requirements.
- Boost development of fish feed alternatives (e.g. algae-based, insects, etc.).
- Increase scientific research on the ecosystem implications of harvesting krill, zooplankton and mesopelagic fish and follow a precautionary approach until these implications are understood.
- Promote more (sustainably) farmed finfish, seaweeds and bivalves in diets.
- Implement and build capacity to enforce strong labour standards for the fishing and mariculture industry.
- Require transparency of seafood supply chains ensuring full ocean-to-plate traceability.

Clean ocean energy: How can the ocean deliver much more zero-carbon energy in a sustainable way?

Why is it important?

Of all the ocean-based climate mitigation options identified (see Chapters 1 and 2), ocean-based renewable energy technologies hold the greatest potential, up to 10 percent of the global needed annual GHG emissions reductions by 2050[553].

The required growth path for ocean-based renewable energy generation is a very aggressive departure from a very low baseline. By the end of 2018 the total worldwide installed capacity of wind energy amounted to 564 GW, of which only 23 GW were offshore[554]. The great majority of installed offshore capacity is in Northern Europe, although there is significant technically feasible generation potential in Brazil (748GW), South Africa (589 GW) and Vietnam (214 GW), as well as Indonesia, India, the Philippines and Sri Lanka[555]. All other ocean-based renewable energy technologies remain at the experimental or demonstration stage today (e.g. wave or tidal power, floating solar).

The target is massive. By several estimates, offshore wind capacity installed will need to be multiplied by a factor of 40 to 45 by 2050 to contribute to a 1.5 degrees compatible trajectory (see Chapter 2). The path from baseline to target is extremely steep—it requires the

Box 3.9. Key Triggers to Boost Clean Ocean Energy from the Ocean

- **Precisely assess local and national opportunities.** Fund the scientific assessment of offshore power resources and site characterisation, including unique weather, oceanographic, ocean ecosystem and seafloor conditions, and design lease tracts accordingly to optimise for development and construction costs, operating conditions, and safety.
- **Formulate national targets.** Announce clear and time-bound national targets increasing the share of offshore wind energy in the national energy mix; set firm operating standards.
- **Develop marine spatial planning** (see Section 3.2, point 2, 'Goal-oriented ocean planning'). Convert these national targets into explicit plans for ocean-based energy development in national marine spatial plans and proactively sort use conflict issues with other ocean users such as fishers, shippers and so on.
- **Offer incentives.** Establish the modalities and schedules for incentive packages, including energy production and investment tax credits, feed-in tariffs and renewable portfolio standards.
- **Streamline administrative processes.** Provide a consistent, efficient and clear permitting process, based on development and operating standards, with predictable timelines.
- **Improve infrastructure.** Reduce the burden of specialised infrastructure cost through appropriate public and joint investments, such as in ocean energy delivery and grid integration, port facilities and properly leveraged existing infrastructure.

installation of around 30 GW/yr. for 30 years, which exceeds the current growth rate by almost an order of magnitude and involves the installation of thousands of turbines per year. Current capacity projections confirm the critical gap: Asian countries are planning for 100 GW of offshore wind by 2030[556] (including South Korea 18 GW, India 30 GW, Japan 10 GW and Taiwan 5.5 GW)[557]. This, combined with the commitments of Europe (70 GW)[558] and the rest of the world, adds up to a 2030 global capacity of about 220 GW[559]—not close to the ambition needed for 2050. But the technical resource is massive, and as the costs of electricity from offshore wind continue to come down below other sources, continued rapid growth is conceivable.

What are the opportunities for action to accelerate change?

The construction of wind farms is a matter of national consensus and political priority, as reflected in regulatory support, public budgets, local support and financial market stability. Technical challenges and economics matter—offshore wind does not make sense for every country or every coastline. Without support from national governments (e.g. country targets for wind power, explicit inclusion of offshore wind in marine spatial plans, infrastructure for grid connectivity and storage), the offshore wind industry will be hard-pressed to build capacity at the scale required to compete with land-based energy sources.

There are other accelerating factors, of course. Institutional investors are not sufficiently knowledgeable about the offshore energy asset class and its risk and return profiles, but they are quickly catching up. Incumbents (utilities, fossil fuel energy generators) may be reluctant to share portside or grid infrastructure. However, with a favourable regulatory and incentive structure in place, these challenges can be overcome. For a summary of these points, see Box 3.9.

Low-carbon transportation and ports: How can a traditional industry embrace sustainability?

Why is it important?

Ocean transport is currently moving around 90 percent of the world's traded goods[560], or about 11 billion metric tons (2018)[561]. There were 94,171 commercial vessels in 2018 globally, mostly bulk carriers, tankers and container ships. Fuelled by increasing global trade, shipping is expected to continue growing above GDP rates in the coming years (the UN Conference on Trade and Development [UNCTAD] is forecasting a 3.8 percent annual growth rate for shipping between 2018 and 2023)[562].

Ocean transport currently produces about 2.2 percent of global greenhouse gas emissions[563], and such emissions are expected to double until 2050[564], in sharp contrast to what is needed to keep global temperature rise well below 2°C and consistent with a 1.5°C increase (IPCC 2013) and align with the goals of the Paris Agreement

(UNFCCC 2015). Decarbonising shipping could also reduce other pollutants usually associated with ocean transport: about 17 percent of the human-induced sulphur dioxide[565] and 8 percent of nitrogen oxide[566] emissions globally. Phasing out such pollution could cut premature deaths by 4,100 by 2030 and 10,000 (annually) by 2050[567].

Ocean-based transportation has the potential for a roughly 100 percent reduction in operational net GHG emissions by changing the way it stores and consumes energy onboard: batteries could be used to store electricity, particularly in ships on the shortest voyages. Low- or zero-carbon synthetic or 'e-' fuels could replace fossil fuels: examples include renewable hydrogen, hydrogen-based fuels such as ammonia, and fuels that have been processed with capture and storage of CO_2. Transitioning ocean shipping to more efficient and low- or zero-carbon fuels, and the mitigation potential in 2030 and 2050, is largely determined by the time scales needed to renew or retrofit the existing fleet and develop the infrastructure to use and supply these new energy sources.

An additional challenge associated with shipping is the discharge of untreated ballast water from ships. It is considered one of the major threats to biodiversity that could have 'severe public health-related, environmental and economic impacts'[568]. One cubic metre of ballast water can contain up to 50,000 zooplankton specimens[569] and/or 10 million phytoplankton cells[570].

Ports, the gateways to the sea, present many challenges themselves. Their operations emit carbon, moving of goods creates significant amounts of air pollution (dust, exhaust), (mishandling of) waste products pollutes local waterways, and the resulting heavy ship traffic creates (underwater) noise. The increase in shipping traffic along ports has been associated with ship strikes[571].

What are the opportunities for action to accelerate change?

Tighten and enforce energy efficiency requirements of ships. Countries should ensure the implementation of the IMO's Energy Efficiency Design Index (EEDI) and move beyond it (e.g. redesign the EEDI formula to ensure that vessels are being optimised for minimised fuel consumption in real operation at sea rather than being optimised only to pass the test[572]), while furthering the goal of fully decarbonising shipping by 2050. To reach these standards, countries should develop national roadmaps, and support the IMO in creating an international one, of how to fully decarbonise ocean transport by 2050.

Test and deploy low-carbon fuels. Countries and shipping companies should foster offtake agreements between ship operators and harbours to incentivise the construction of zero-carbon fuel infrastructure and ensure its use by shipowners. These low-carbon fuel offtake agreements are essential to overcome the chicken-and-egg problem of building low-carbon fuel infrastructure in harbours versus building the ships requiring such low-carbon fuel infrastructure.

Incentivise decarbonisation of shipping. Governments should set clear port access targets based on carbon emission standards and/or tax ship GHG emissions or create emission trading systems for shipping companies.

Eliminate port air pollution through environmental regulations. This includes electrifying port operations and making shore power available for ships. It also includes integrating ports into local decarbonised land transport systems to ensure continued low-impact transportation of goods and people.

Harmonise port operations with the local environment. This includes ensuring that port expansions do not destroy sensitive habitats. High-traffic shipping lanes usually associated with ports should be planned in accordance with whale migrations to minimise ship strikes. Ports should not be expanded into sensitive habitats or built in locations requiring continuous harmful dredging.

Support retraining programs for port and ship jobs that are expected to be automated. Ports are often major employers within their region. Increased automation can replace jobs while raising the average skill level demanded of the retained employees.

Box 3.10. Key Triggers to Decarbonise Shipping

- Tighten and enforce energy efficiency requirements of ships.
- Test and deploy low-carbon fuels.
- Incentivise decarbonisation of shipping.
- Eliminate port air pollution through environmental regulations.
- Harmonize port operations with the local environment.
- Support retraining programs for port and ship jobs that are expected to be automated.

Governments should support retraining programs for current port and shipping works to ensure that there is no skills gap, while retaining a maximum of current employees. For a summary of these points, see Box 3.10.

Ocean restoration and protection: How can protected areas be mainstreamed and enforced?

Why is it important?

A century or more of coastal urbanisation, ocean and coastal resource exploitation, infrastructure expansion, river channelling, land reclamation, mangrove removal and pollution has taken its toll. Globally, an estimated 50 percent of salt marshes, 35 percent of mangroves, 30 percent of coral reefs and 29 percent of sea grasses have been either lost or degraded[573]. By 2100, as many as 630 million people could be at risk of coastal flooding caused by climate change[574], with several atoll states in danger of disappearing entirely[575].

Reversal of these trends is urgent. Intact coastal ecosystems provide critical services to all of humankind. They are critical to fisheries and recreation. They protect cities and coasts from storms and sea level rise. They host unique biodiversity.

An ecologically healthy coast does, of course, have intrinsic economic value, offering protection from storms, surges and swells[576], the nursery of coastal fisheries[577], recreational value and so on. However, a narrowly defined economic metric is unlikely to win the day for the coast—short-term cost-benefit calculations can just as well make the case for coastal destruction[578] and they certainly do not account for the damage done when ecological thresholds are irreversibly crossed[579].

That said, some monetisation of coastal ecosystem values is possible—the storm protection and wave attenuation services of healthy coastal biota, for example, have been well documented. Over 500 million people worldwide live in a coastal zone that is protected by coral reefs[580]. Without their protection, flood damages from 100-year storms would increase by 91 percent to $272 billion[581]. U.S. coastal wetlands provide $23.2 billion a year in storm protection services—a benefit of over $33,000 per hectare (median $5,000 per hectare)[582]. Mangroves reduce annual flooding globally by more than 39 percent per year for 18 million people, and reduce annual property damage by more than 16 percent, or $82 billion[583]. Similarly, the value of coastal ecosystems in terms of nursery and habitat for fishes and other marine species, regulation of water flow and filtration, carbon sequestration, and contaminant storage and detoxification has also been calculated for coastal habitats, ranging from $100 to $10,000 an acre[584].

The greatest risks of coastal degradation are to populations already at risk on other fronts. Forty-six percent of Bangladeshis live within 10 metres of sea level, with declining levels of storm protection from mangrove forests. Developing countries account for 9 of the 10 nations with the largest share of the population living in low-elevation areas (the Bahamas, Bangladesh, Belize, Djibouti, Egypt, the Gambia, Guyana, the Netherlands, Suriname and Vietnam)[585]. In the United States, approximately 39 percent of residents of coastal counties fall into an elevated coastal hazard risk category (i.e. children, the elderly, households where English is not the primary language and those in poverty)[586]. When Hurricane Katrina's storm surge reached New Orleans with almost no interference from its highly degraded surrounding wetlands, nearly 85 percent of people killed were aged 51 and older, and almost half were older than 75 years of age[587].

Upstream river management aimed at flood protection, irrigation and hydroelectric power generation have resulted in drastic sediment imbalance and have accelerated coastal erosion by depriving coastal landscapes of sand or silt[588]. Globally, an estimated 25 percent to 30 percent of the total suspended sediment flux is potentially trapped in artificial impoundments of about 45,000 reservoirs[589]. This reduces marine sediment supply to deltas and estuaries[590]. If no mitigation measures are undertaken and sediment retention continues, approximately 28,000 km^2 of the deltaic area in 40 deltas could suffer from increased flooding and coastal erosion by 2050[591]. Uncoordinated upriver flood protection has proved to be counterproductive, as the flood risk is often simply transferred and amplified to downriver communities[592]. The river deltas are paying the ultimate price, as they have no way to escape the erosive effects of faster and more intense river flows.

What are the opportunities to accelerate change?

Map and account for benefits. A comprehensive mapping of the areas of high diversity, productivity, carbon concentration, coastal protection from sea level rise and storms, fishery support (nursery habitat and other critical life stages) and tourism values is the essential foundation of planning and must be the first priority. Such mapping informs sustainable ocean economy planning, national greenhouse gas inventories (if conforming to IPCC 2013 protocol) and nationally determined contributions (NDCs). The carbon flux and sequestration capacity of reefs, mangroves, sea grasses and salt marshes should be systematically accounted for. To the degree that the capacity for such rapid, accurate and comprehensive ocean mapping efforts is not in place in every country, technical assistance may be required (see Section 3.2, point 2, 'Goal-oriented ocean planning').

Integrate restoration and protection into sustainable ocean economy plans. With a comprehensive ocean resource mapping in hand, protection and restoration or regeneration need to be systematically merged into a sustainable ocean economy development planning process (see Section 3.2, point 2, 'Goal-oriented ocean planning'). The baseline ambition needs to be a global fully protected set-aside of 30 percent of the ocean for coastal protection, fishery recovery, biodiversity restoration, controlled recreation and so on. With proper planning this can be fully complementary to the economies of fishing (stock restoration), tourism (diving, pristine areas), offshore wind (protected buffers around turbines), shipping (avoided risk of whale strikes, safe distance from turbines), mariculture (vibrant, nutrient-rich, healthy ecosystems) and the protection of coastal assets (storm-surge protection). Conservation and restoration or regeneration should be regarded as a fully legitimate sector of the sustainable ocean economy, with its own economic logic, financing sources (carbon, wetland and nutrient credit and offset markets; carbon finance; infrastructure funding), and fully accountable and measurable contribution to both 'flow' (i.e. gross value added) and 'stock' (i.e. natural capital) metrics.

Include quantified nature-based solutions in nationally determined contributions and other relevant climate policies for mitigation and adaptation. Ocean-based mitigation options do not feature as prominently as they could in countries' NDCs or long-term low greenhouse gas emission development strategies under the Paris Agreement[593]. This is an extremely important moment, as emphasised by the IPCC (2018): the chances of 'failing to reach 1.5 degrees Celsius [will be] significantly increased if near-term ambition is not strengthened beyond the level implied by current NDCs'. Given the consequences of failing to limit global average temperature rise to 1.5°C, or at least to 'well below' 2.0°C, capturing the potential offered by blue carbon in NDCs could forcefully accelerate restoration and protection of these ocean and coastal natural assets.

Connect ocean protection and restoration with land-based initiatives and stakeholders. Coastal restoration and protection cannot succeed in isolation. Delta restoration requires river management that optimises sediment flows. Near-coast MPAs are highly sensitive to nutrient contamination. Symbiotic MPA, mariculture and energy projects require clean and abundant freshwater flows. For example, Florida's Apalachicola Bay once housed the highest concentration of oyster beds in the United States. As the abundant waters of the Apalachicola River were depleted by growing upriver cities, the beds atrophied, and today only small remnants of the oyster industry remain. Restoration of the bay would require close coordination with upriver water and reservoir managers to optimise freshwater flows. Most comprehensive, EEZ-wide ocean planning efforts thus need to closely coordinate with river authorities. For a summary of these points, see Box 3.11.

Box 3.11. Key Triggers to Restore and Protect Nature

- Map and account for benefits.
- Integrate restoration and protection into sustainable ocean economy plans.
- Include quantified nature-based solutions in nationally determined contributions and other relevant climate policies for mitigation and adaptation.
- Connect ocean protection and restoration with land-based initiatives and stakeholders.

Tourism: How can tourism be turned into a zero- or positive-impact industry?

Why is it important?

Tourism is estimated to contribute to about 10 percent of the world's economic activity and is a key source of foreign earnings for many developing countries[594]. The industry has been growing steadily over the last half century. Between 1965 and 2019, the number of international tourists alone has increased about 13-fold: from 113 million in 1965 to 674 million in 2000 to 1,461 million in 2019, a trend that is expected to continue[595]. It is hard to determine how much of the global tourism is purely coastal, but there are good indications that a significant amount of it is. Over 46 percent of Europeans, the largest group of international travellers, cited 'beach access' as their holiday travel reason[596]. Estimates vary, but between 60 and 350 million people annually travel to the world's coral reef coasts[597]. In many coastal nations, coral reefs support over one-quarter of all tourism value and over 6 percent, and up to 40 percent (about 43 percent in Palau and in the Maldives) of the nation's GDP[598]. Cruise tourism, growing strongly, is predicted to move 30 million people across the ocean (2019), up from 18 million a decade ago[599].

The growth of the coastal tourism industry came at a price for coastal ecosystems. The negative impact of tourism on ecosystems is well documented and threatens the long-term socioeconomic value of the industry itself. Much like other natural resource–based industries, tourism can deplete the very resource it most depends on, in this case, a healthy and beautiful ocean environment. Unlike other industries, however, 'sustainable yield' is not clearly defined in tourism, and most of the industry operates outside internationally accepted certifications and transparent performance standards. The resulting damage has been exemplified by the closure of Maya Bay in Thailand, the degradation of near-shore reefs in Indonesia and the massive destruction of coastal wetlands by tourism development. The concentration of tourism further intensifies the impacts: destruction of natural habitats, excessive groundwater extraction leading to saltwater intrusion, introduction of exotic species and sewage pollution, to name just a few[600].

The sector is also constrained by the deterioration of its target areas by outside forces. As early as the 1960s, human-driven eutrophication of the Black Sea led to a decline in tourism revenues of $500 million[601]. Today, cleaning beaches in the European Union alone costs over €413 million per year[602]. Having already put a very high strain on the environment, using the tourism industry as a force for sustainable growth rather than environmental destruction will be critically important.

The COVID-19 pandemic has had major effects on tourism: because of the lockdowns and travel ban implemented in most countries, tourism is expected to lose $2.1 trillion in GVA in 2020, with 100 million jobs at risk[603]. This sudden and massive hit on the tourism industry raises existential questions: Will this be an opportunity to reinvent tourism as an eco-friendly experience? Is this a hard stop from which the industry will not recover? Will the industry rebuild as it was before?

What are the opportunities to accelerate change?
Countries and tourism operators should consider a number of possible approaches when thinking about the future of coastal and ocean tourism:

Create national tourism strategies and implement governance systems that ensure the sustainable and equitable development of the tourism industry. These plans should include a clear spatial plan for the sustainable, climate-smart expansion of tourism resorts, and ensure capacity for waste and traffic infrastructure to cope with the increase in tourism. The plans could also include requirements for certified climate-friendly travel as conditions for accepting tourists to points of interest or even to the country.

Implement tourism taxes as payment for ecosystem services the industry relies on. The revenue from these taxes should be used to restore degraded nature and maintain coastal and marine ecosystems. Additionally, it can provide a source of funding to build the necessary infrastructure and help the local tourism industry transition to a more sustainable operating model. A back-of-the-envelope analysis reveals the potentially enormous contribution of such a tourist ecosystem service tax: assuming that one-third of international tourism is coastal and an (only) 1 percent ecosystem tax is levied on international tourism expenditures (roughly $1,500 billion[604]), $5 billion in funds would become available for coastal and marine ecosystems—four times the current marine philanthropic funding and official development assistance combined[605].

Agree on and implement international environmental standards for coastal tourism. New, more ambitious environmental standards could become the norm for the tourism industry after COVID-19. Much-needed standards regulating the coastal and cruise tourism industry with respect to its CO_2, air, over-tourism, waste and effluent pollution should thus be created and implemented internationally. Ideally, the tourism industry itself would advocate for and hold countries to adopt these standards as the tourism industry itself benefits from a healthy ocean. For a summary of these points, see Box 3.12.

Box 3.12. Key Triggers to Turn Tourism into a Zero- or Positive-Impact Industry

- Create national strategies for sustainable tourism growth.
- Implement tourism taxes as payment for ecosystem services.
- Agree on and implement international environmental standards for coastal tourism.

3.3. Launching the Voyage: Three Levels for Possible Immediate Action

The voyage needs to start not with a bang but with a thousand rising voices. A set of expert recommendations can provide very helpful guidance for decision-makers, but it will only make a difference if the solution works for its beneficiaries—economically, culturally and socially.

Launching the voyage is about creating self-evident movement, a sense of inevitability, by building on the work already underway—the networks of innovators (in both industrialised and developing countries) who are the living embodiments of the overall change that is needed. It is far more about anchoring the transition to tomorrow in the reality of today than it is about theoretical best practices.

There is no shortage of such innovators—in policy, technology, resource management, inclusion, governance and so on. These business ventures, technology trials, corporate coalitions, investment partnerships, civil society programs and policy innovations are at the heart of a great experiment the world needs in testing, failing and learning.

Standing on the shoulders of these pioneers, this final section of the report suggests three ideas for a quick start towards change. These ideas do not pretend to be silver bullets, or to be exhaustive and to replace existing initiatives led by governments, businesses and civil society. These ideas are suggestions for interventions that are expected to create a snowball effect and accelerate change towards a sustainable ocean economy, in complement to the broader, more comprehensive action agenda presented in Section 3.2.

These suggested ideas to launch the voyage are especially critical in the context of the post-COVID recovery. They constitute concrete propositions to rebuild the economy bluer, more sustainable and more resilient, at a time when many hold onto business as usual for their own survival and advocate for postponing ambitious sustainability reforms.

At the local level, this report introduces the concept of sustainable ocean economic zones (SOEZs), which could become laboratories and demonstrators of the broader ocean action agenda, in complement with broader science-based planning for the entire EEZ, and ultimately for the high seas. At the national level, inspired by a successful international track record, the report considers the establishment of national ocean delivery task forces. Finally, at the international level, several no-regret moves and potential collaboration areas are encouraged.

Local intervention: Catalysing change through sustainable ocean economic zones

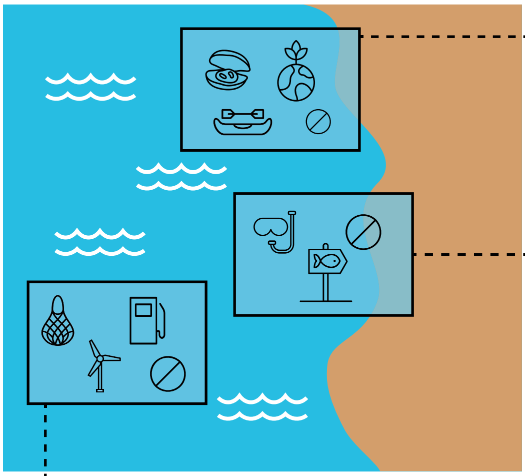
On land, special economic zones are a long-established and well-proven component of industrial strategy. Typically, these zones provide a shell within which select ventures can thrive, offering low rents, low taxes, low utility and infrastructure costs, relief from heavy bureaucratic procedures, and low-cost debt from central government funds, providing guarantees to market-rate investors. These zones have been used to attract new businesses to revitalising urban areas, support emerging and high-risk industries, promote cooperative business models, stimulate exports and so on. They scale from small neighbourhood zones to entire cities (e.g. Dubai, Shenzhen and Hong Kong).

If done correctly, with all planning, legislation, approval, construction, investment and operation carefully designed to be fit for the intended purpose, and by respecting labour rights and social sustainability, they can be quite successful. There are 5,400 zones in over 147 nations today, directly employing between 90 and 100 million workers[606].

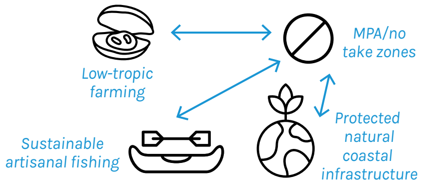
With very few exceptions, they have not been used to promote a sustainable ocean economy. There have been hurdles: the concept of spatial planning and restricted access in the ocean commons is often controversial, the siting of permanent ocean structures is politically difficult and any alternative to the current 'free for all' has not been mainstreamed yet.

Replicating the success of the (sustainable) economic zone concept in nations' EEZs might prove to be a powerful catalyst in accelerating a local sustainable ocean economy. Sustainable ocean economic zones could provide a testbed for systemic experimentation and innovation, a way for nations to support and evaluate the sustainable ocean economy model at a scale they are comfortable with. For different nations, such zones can look very different in almost every respect (Figure 3.9). Some industrial nations, for example, can use them to attract and test high-technology models that combine energy generation, shipping and large-scale mariculture. A low-lying coastal nation may use them to combine carbon-financed restoration, coastal protection, tourism and fishery enhancement. Another country may concentrate on the symbiotic mariculture of many types of seafood in one place, combined with ecotourism.

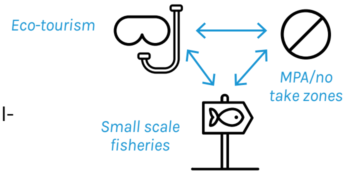
Figure 3.9. Illustrative Examples of Sustainable Ocean Economic Zones



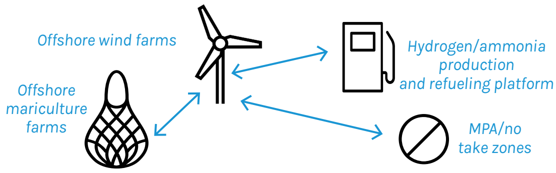
EXAMPLE 1
minimum 1,000 sq km
- Warm temperature year round
- Natural beaches
- Coral reefs
- Growing tourism industry



EXAMPLE 2
minimum 1,000 sq km
- Estuary/salt marshes/ mangroves/beaches
- Artisanal fishing and small-scale coastal mariculture
- Emerging tourism



EXAMPLE 3
minimum 1,000 sq km
- Abundant wind
- Industrialized ocean (e.g., offshore oil and gas platforms)
- Shipping lanes nearby



There is no "one size fits all" model

The ocean economic activities in a given zone need to be determined locally as a function of:

- Biophysical characteristics of the area (temperature, natural assets, fish stocks, wind availability, etc.)
- Existing industries and human activities in the zone
- Willingness of local players to engage in a sustainable ocean transformation

COMMON MANAGEMENT ELEMENTS TO ALL OF THESE OCEAN ECONOMIC ZONES

- Dense network of sensors allows scientific monitoring of the zone
- Actions are undertaken in the coastal area nearby the zone to limit land-based pollution
- Economic health and sustainability of the zone is controlled by a digital dashboard
- 100% of the zone is managed according to a plan, developed in a collaborative process with zone users
- Tailor-made financing mechanisms and guarantees are provided by public sources
- Scientific attention is made to ensure benefits are redistributed equitably to communities and women

Source: Authors.

A country's path to the design of a sustainable ocean will likely involve a series of steps:

- **Use case and delineation.** Using a working group of existing ocean users, technologists, financiers and public sector heads, an initial ocean industrial strategy could be developed that helps to identify which special zone models a nation wants to test in its EEZ (Figure 3.9). This would determine the required utility of each zone (its 'use case') in terms of the types of ventures targeted, their siting and infrastructural requirements, their inherent potential symbiosis or conflict with other sectors and so on. For example, a special use zone focused on the symbiotic production of multiple trophic levels of food would have very different siting needs from an area focused on renewable ocean energy production. Each ocean SOEZ would then be delineated more precisely as a function of the specific use case, based on the biophysical characteristics of the area (temperature, natural assets, fish stocks, wind availability, etc.), existing industries and human activities, and the willingness of local players to engage.
- **Legislative certainty.** Once the use case is established, governments would need to approve the zone's placement and guarantee the zone's long-term authority to provide use rights to its tenants. This will be critical since it creates a lasting, easily navigable legislative framework within the SOEZ that gives certainty to investors.
- **Commitments and privileges.** The terms of the SOEZ contract—the commitments and privileges—need to be made very clear. At a minimum, participants should commit to the following:
  - A net-regenerative balance of production and protection—such as more carbon saved and sequestered than released, net habitat restored and so on.
  - Inclusion of multiple linked sectors—such as energy and food, multi-trophic food, restoration, tourism and so on.
  - Compliance with safe operating principles—such as mariculture standards for feed, containment, disease control, fouling and so on.
  - Equitable practices—such as preference for local market distribution, adherence to labour standards and respect of human rights, and support for women and marginalised groups.

A set of 'privileges'—specific support packages provided by the government—needs to be tailored to the purposes and uses of each zone. In general, these will require measures to increase margins (low-cost onshore infrastructure access, price guarantees), reduce risk (offtake guarantees, streamlined permitting, insurance vehicles), reduce capital costs (below-market debt, tax breaks) and bring in market-rate debt.

In practice, the efficient provision of below-market debt may require the pooling of resources. For example, several sovereign wealth funds may pool resources to create an ocean economy debt fund providing subsidised debt to the SOEZs of participating countries. Ideally, this would be used to guarantee a matched fund provided by a coalition of development finance institutions. This concentrated and coordinated approach would have the dual benefits of (1) systematically de-risking the investment in emerging industries and (2) creating a pool of domain knowledge and capacity ahead of the market. Both benefits are essential to attracting investments from the institutional finance community, which, today, remains largely unfamiliar with the ocean economy realm and is structurally risk-averse.

To qualify for access to this fund, SOEZs would have to fulfil basic economic and ecological requirements—an additional measure of quality assurance. For example, they could require that an SOEZ have signed up a minimum critical number of anchor tenants, that coastal infrastructure be available and accessible, and that sponsoring nations provide sufficient cost and demand supports. It is essential that the link between the 'commitments' and the 'privileges' be explicit—these zones cannot become oases for cheap profits and minimum performance.

- **Adaptation and learning**. What matters most is that SOEZs be deliberate—they are meant to provide a contained laboratory and demonstration arena, where incentives can be concentrated and tested, results collated and adapted to, and risks managed. In the process of designing, launching and implementing the zones, the classic hurdles to ocean management—free access, lacking planning, use conflicts and free externalities—should be addressed in the context of real business, rather than abstract policy. Finally, SOEZs would be knowledge-intensive. When things go wrong, experiments fail and conflicts arise, the lessons learned would be reflected in the SOEZs' design and operations. On land, special economic zones have clearly evolved from an emphasis on manufacturing, trade and exports to a focus on knowledge, such as new technology frontiers and research and development (R&D).

- **Scaling the model**. Experience on land has shown that special economic zones today are instruments for the support of emerging technologies and business concepts and are not infinitely replicable. The goal is to accelerate commercialisation to the point where market-rate institutional capital moves in. In the case of SOEZs, there is an additional goal: to demonstrate the business case for a more systemically managed and accessed ocean, and to create a new, self-interested set of communities ready to defend their health on economic grounds.

SOEZs are a possible catalytic experiment for a sustainable ocean economy. They are bespoke, limited in scope and risk, and high in knowledge development. They can catalyse a new epoch but need to be supplemented by the array of more systemic policies and business priorities described in this report's action agenda (Section 3.2) and by additional catalytic interventions at national and international levels (see below). In the medium term, lessons learned from the SOEZs established by pioneering countries or regions should be codified in global standards, protocols, evaluation frameworks and the like to allow more countries to launch their own SOEZ without having to test and learn all dimensions of the concept.

National intervention: Getting things done with national ocean task forces

In recent years, the art and science of complex change management has been greatly refined and codified. Long familiar to the private sector, the principles of performance management have been applied to the public realm, with great success in increasing the performance of such complex networks as schools, health care, security and transportation systems, with measurable and transformative impact on metrics such as test scores, crime rates, health outcomes and the like. Typically, these approaches work even in the challenging context of multiple agencies and jurisdictions, conflicting objectives, complex logistics and significant uncertainty—as long as the approach is an extension of senior leadership. In general, these types of approaches involve small, non-hierarchical and highly competent teams, led by very senior and respected managers, with full access to all relevant information and working under a powerful and time-constrained mandates and targets.

Additionally, these task forces should appropriately represent all kinds of diversity and communities in their members, or at least represent them through thorough consultations.

Originally conceived in 2001 by Tony Blair as a 'Prime Minister Delivery Unit', this approach is now widely used. In the past two years alone, more than a dozen other governments—including those of Costa Rica, Ghana, Kenya, New South Wales (Australia), Pakistan, Peru, Saudi Arabia and Serbia—have created such units (see Figure 3.10). Results can be quite encouraging (with necessary caution with respect to how metrics are calculated). In Britain, the number of people waiting more than a year for surgical procedures fell from over 40,000 to below 10,000; in Malaysia, reported street crime fell by 35 percent between 2009 and 2010; in Pakistan's Punjab province, the vaccinator attendance rate rose from 22 percent to over 90 percent between 2014 and 2015; in the U.S. state of Maryland, infant mortality dropped from 8 per 1,000 live births in 2008 to 6.5 per 1,000 live births in 2014[607].

In the context of the shift to a sustainable ocean economy, this delivery unit approach can be very powerful if done right.

In the Dutch North Sea EEZ, for example, the need for explicit spatial planning became abundantly clear in 2015. Sand mining, oil drilling, dredging, cabling, shipping, military manoeuvring, land reclamation, fishing, aquaculture, wind energy and recreation had been accommodated in an integrated management plan since 2005—but the plan lacked explicit spatial guidance. A newly announced subsidy for wind farms led to 75 proposed projects and an unmanageable tangle of overlaps and potential use conflicts—with no relevant rules in place. For example, what would be a safe distance between a wind farm and a shipping lane where 400-metre tankers would pass by? The ministers mandated a full, spatially explicit plan which combined zoning for MPAs in six main sectors of national importance: shipping routes, oil and gas installations, carbon capture and storage, renewable energy, defence and sand mining. Also, explicit rules were made to resolve potential conflicts between these priority functions[608]. The process—clearly mandated at the ministerial level, extensively consultative, highly expert, science-driven, target- and performance-oriented, and time-constrained—was a classic delivery unit approach. The approach could be similarly used to design ocean sustainable economic zones, develop multi-sector ocean development concepts, plan restoration projects or MPA networks and the like, within the 100 percent managed EEZs.

A first implementation step for the shift to a sustainable ocean economy could thus be the appointment of an SDG 14 (sustainable ocean) task force—appointed at the (ocean) ministerial or head of state level, and with an

Figure 3.10. Location of Existing Centre-of-Government Delivery Units (National and Regional Levels)

NORTH AMERICA

Canada
Results and Delivery Unit, *2016*

Maryland, USA
Governor's Office of Performance Improvement, *2015*

CENTRAL AND SOUTH AMERICA

Colombia
Unidad de Ejecución, *2015*

Costa Rica
Centro de Gestión de Gobierno, *2015*

Guatemala
Equipo de Prioridades Presidenciales, *2016*

Paraguay
Centro de Gobierno, *2013*

Peru
Unidad de Cumplimiento de Gobierno, *2016*

EUROPE

Albania
Delivery Unit, *2013*

Romania
Delivery Unit, *2014*

Serbia
Delivery Unit, *2015*

United Kingdom
Implementation Unit, *2012*

AFRICA

Gauteng, South Africa
Delivery Unit, *2016*

Ghana
Presidential Delivery Unit, *2015*

Kenya
Presidential Delivery Unit, *2015*

Liberia
Programme Delivery Unit, *2010*

Rwanda
Government Action Coordination Unit, *2008*

Senegal
President's Delivery Unit, *2014*

Sierra Leone
President's Delivery Team, *2015*

Uganda
Prime Minister's Delivery Unit, *2016*

Western Cape, South Africa
Delivery Support Unit, *2014*

MIDDLE EAST

Jordan
Prime Minister's Delivery Unit, *2015*

Oman
Tanfeedh Delivery Unit, *2016*

Saudi Arabia
Central Delivery Unit, *2016*

ASIA AND AUSTRALIA

Brunei
PENGGERAK, *2014*

India
Delivery Montoring Unit, *2009*

Indonesia
UKP4, *2009*

Khyber Pakhtunkhwa, Pakistan
Strategic Support Unit, *2015*

Malaysia
Performance Management Delivery Unit, *2009*

New South Wales, Australia
Premier's Implementation Unit, *2015*

Pakistan
Prime Minister's Delivery Unit, *2015*

Punjab, Pakistan
Special Monitoring Unit, *2014*

Source: Gold, J. 2018. "Tracking Delivery." Institute for Government. https://www.instituteforgovernment.org.uk/sites/default/files/publications/Global%20Delivery%20report.pdf.

incontrovertible mandate to translate the sustainable ocean agenda into the appropriate national context by undertaking the following actions:

- Conduct a comprehensive marine resource mapping effort covering the entire national EEZ.
- Support and facilitate a participatory, inclusive process to develop an ocean plan which provides explicit guidance to assure the avoidance of spatial use conflicts, uniformly high standards of operation, a streamlined and efficient regulatory process, the integration of symbiotic ocean uses and the overall protection and sustainability of the key oceanic systems (in a minimum of 30 percent of the ocean as protected areas).
- Advise the relevant ministries and head of state on the specific steps required to further accelerate a regenerative ocean economy, including the design of special sustainable ocean economy zones, financial guarantees and risk reduction measures, policy and regulatory implications, and international coordination issues.
- Lead special technological and bureaucratic initiatives—in coordination with relevant existing organisations, academia and civil society—such as the design of MPA networks, the detailed design of special sustainable economic zones and the recommended approach to controlling land-based pollutants.

In keeping with the basic delivery unit principles, this task force will have to be carefully set up and mandated. The following basic requirements would need to be met:

- The mandate would be issued formally and publicly at the ministerial and/or head of state level and clarify all mandate overlap issues with the appropriate federal and state agencies.
- The task force would be granted full access to all government-owned data sets (excepting only those of considerable national security significance).
- A firm timeline of deliverables would be provided.
- The task force would be provided with a core team of highly competent technical experts, full agency technical support and sufficient funding.
- The heads of all relevant agencies would be formal members of the task force governance and personally accountable for its success.
- The task force would have the full authority to conduct outreach and consultation in the name of the mandating minister or head of state.

Some countries will be better resourced and prepared to embark on this approach than others. Steps should be taken to develop a technical support platform which can provide targeted assistance to requesting nations, such as advanced capabilities in geographic information systems and mapping; resource mapping and sensing; protected area network delineation and design; operational standard setting for key industries; sector-specific knowledge (wind energy, mariculture, shipping safety); project finance and so on.

Some other countries might find that this approach is not suited to their culture and usual way of working and will have to consider a different, tailor-made approach.

This task force approach can be very efficient when short-term results and impacts are expected, such as in post-COVID recovery, where immediate solutions are expected to re-boost the economy and create jobs while avoiding the replication of environmentally detrimental practices from before COVID-19. For instance, national ‘blue task forces’ could be set up to support some immediate ‘blue’ recovery priorities, as identified in the latest special report commissioned by the Ocean Panel[609]:

- Coastal and marine ecosystem restoration and protection
- Sewage and waste infrastructure
- Sustainable non-fed mariculture
- Zero-emission marine transport
- Sustainable ocean-based renewable energy

These priorities are fully in line with the action agenda presented in Section 3.2 and could constitute a good starting point to embrace a more holistic transformation journey towards a sustainable ocean economy at scale.

International intervention: Raising the bar

Local and national interventions can generate significant catalytic effects but should not underestimate the importance of international collaboration. Indeed, several international agreements, treaties and conventions have already identified the challenges and solutions required but are still insufficiently ratified and poorly enforced. In addition, a growing number of global initiatives underway related to the sustainable ocean economy would benefit from additional recognition and support.

The following **international treaties, agreements and conventions** can greatly help accelerate a sustainable ocean economy:

- **The Paris Agreement.** 'The' landmark climate agreement aims to reduce global emissions to keep the planet's warming to 'well below' 2 degrees (Celsius) and to pursue a 1.5-degree future warming scenario[610]. Of 197 parties, 189 have ratified the agreement, covering 97 percent of the world's emissions[611]. Instead of settling on a minimum common denominator, individual country commitments to the climate agreement are made through nationally determined contributions, allowing each country to commit as much as it is able—or willing—to contribute. As of 2020, only a handful of countries are on track to meet their climate goals[612]. It is critical that all countries ratify commitments made under the agreement to maintain the ocean, while expanding their NDCs to include the wealth of ocean climate-mitigation opportunities.
- **The Agreement on Port State Measures** is the first binding international agreement to specifically target IUU fishing. Its innovative approach is to prevent vessels engaged in IUU fishing from using ports and landing their catches, an approach assumed to be more cost-efficient than tracking and pursuing these vessels at sea. As of 2019, 105 countries are committed to the implementation of the agreement, but many of them are still struggling with the financing and capacity needed to fully enforce it[613].
- **The Hong Kong Convention** is aimed at 'ensuring that ships, when being recycled after reaching the end of their operational lives, do not pose any unnecessary risks to human health, safety and the environment'[614]. To achieve this goal the convention also covers the design, construction, operation and maintenance of ships and can encourage circular design[615]. Although it was adopted in 2009, the convention cannot enter into force until it is ratified by '15 States, representing 40% of the world's merchant fleet and their ship recycling volume constituting not less than 3% of the gross tonnage of these contracting States' merchant fleet'[616]. Yet, as of 2019, it had been ratified or acceded to by only 12 states: Belgium, Denmark, Estonia, France, India, Japan, the Netherlands, Norway, Panama, the Republic of the Congo, Serbia and Turkey[617].
- **The Intergovernmental Conference on Marine Biodiversity of Areas beyond National Jurisdiction (BBNJ).** This process, being negotiated under UNCLOS, represents 'an opportunity to provide a new governance model with legal clarity'[618] for the global commons in areas beyond national jurisdiction, including (1) a path to designate, implement and manage area-based management tools, including marine protected areas; (2) a trigger and a process for carrying out environmental impact assessments; (3) ensured fairness and equity of access to and benefit-sharing arising from the use of marine genetic resources; and (4) a means to foster developing capacity and transfer of technology to countries in need[619]. As soon as an agreement on marine biodiversity of areas beyond national jurisdiction is adopted, ocean-minded countries should ratify, implement and operationalise it.
- **The Convention on Biological Diversity**. Entered into force in 1993, the Convention on Biological Diversity (CBD) aims to conserve biological diversity, promote the sustainable use of the components of biological diversity and ensure the fair and equitable sharing of the benefits arising from the use of genetic resources[620]. Under the CBD, Parties are negotiating the post-2020 global biodiversity framework, to be adopted at the 15th meeting of the Conference of the Parties (COP 15) in China in 2021. This framework will contain a new set of global goals and targets for biodiversity, and it is crucial that ambitious targets be agreed on to support a healthy ocean and a sustainable ocean economy.

In addition, the IMO, regional fisheries management organisations, regional seas conventions and others provide tools that can be used much more actively. It would also be possible to establish regional ocean management organisations that manage the ocean cross-sectorally, to seek international support for a Paris-like agreement for the ocean and to set up a task force on ocean-related financial disclosures. Another possible tool is a global ocean accountability board, composed of leaders from a number of sectors, which sits outside the international forums and seeks to (1) avoid catastrophic ocean collapse and (2) hold the world to account for its ocean action[621]. This panel would be modelled on the G20 Financial Stability Board.

In addition, the idea of creating a supranational ocean agency of some kind could be explored. Learning the lessons from UNESCO's 'Man and the Biosphere' programme[622], this institution could be mandated to provide a flexible set of frameworks and protocols to empower local actors to collaborate, with the goal of protecting and regenerating ocean commons at regional levels[623]. This ocean agency could be created by UN resolution, or it could be created by a founding group of nations who invite others to participate. Its establishment should ensure legitimacy and safeguards against capture by special interests[624].

A key to sustainable development and to developing a sustainable ocean economy is a cross-sectoral approach. Given the complexities of international law, access to ocean resources and various constraints, it is likely that polycentric systems of governance will prevail[625]. A thorough expert review of the existing governance mechanisms and how they should be changed to support the development of a sustainable ocean economy is beyond the scope of this report. However, such a review should be performed as a matter of urgency.

Beyond the purely political efforts mentioned above, a growing number of initiatives are gathering a variety of actors willing to accelerate a sustainable ocean economy. Supporting such initiatives is a concrete immediate next step to advance a shared vision, identify solutions to remove roadblocks and initiate public-private partnerships. None of the identified ocean challenges and opportunities can be solved or captured by one entity alone—bringing together the private sector, public entities and civil society along the journey and identifying stakeholders on the ground that are willing to support efforts to address system change is key. Building coalitions around certain ocean themes can help align stakeholders into a unified voice, build on synergies and help identify and develop high-impact, investable opportunities.

Conclusion

This report has argued that the agendas of effective ocean protection, sustainable ocean production and equitable human prosperity are inseparable and compatible. It has framed the economic, social and ecological upside of getting the ocean economy right—and the deeply concerning and potentially sweeping consequences of getting it wrong.

Getting it right means a fundamental shift away from the 'free for all' model, which assumes an ocean of unlimited potential to regenerate, dilute and absorb. This model is maintained by current practices, laws and cultural norms, but it is not inviolate. Spearheaded by a new cohort of ocean interests deeply vested in ocean health—including sustainable fishers and mariculturists, coastal communities, renewable energy generators, tourism operators, scientists, environmentalists and social and civil society organisations—pollution and over-exploitation can be powerfully counteracted. It will require thoughtful policy support, including transparent and comprehensive national ocean planning, mandatory standards for open data access, investment of (sovereign wealth, development and private) capital, new legal protections from polluters and a national accounting approach focused on the ocean's natural capital and production in equal measure.

The report argues further that the ocean's essential contribution to sustainable planetary food and energy production can be achieved without abandoning a precautionary, insurance-based approach. The consequences of systemic failure in the ocean are grave, and there is no logic in 'harming the ocean to save the planet'. The approach calls for the inclusion of at least 30 percent fully protected areas at a global scale, the avoidance of new extractive activities whose impact is not fully understood and the widespread adoption of rigorous operation standards for all ocean uses.

Learning from the successes and stalling points of other industrial and societal transformations, this report has developed a comprehensive 10-point action agenda for a sustainable ocean economy. Further, it proposes three concrete options to commence and accelerate change: sustainable ocean economic zones, centre-of-government delivery units and interventions at an international level.

The journey towards a sustainable future has already begun, with pioneers leading the way. New sustainable technologies are attracting investors, and businesses and governments are waking up to the opportunities of a sustainable ocean economy—as well as to the risks and cost of inaction. It is an enormously inspiring journey. Antoine de Saint-Exupéry describes the awe and wonder that the ocean evokes, and the power of humanity's determination to connect with it: 'If you want to build a ship, don't drum up people to collect wood and don't assign them tasks and work, but rather teach them to long for the endless immensity of the sea'[626].

The COVID-19 pandemic has severely hit most ocean-based sectors, with significant social and economic impacts. Without deprioritising the need for immediate responses and quick recovery, this shock could also be seen as an opportunity to accelerate the transition towards a sustainable ocean economy. As Arundhati Roy observes, 'Historically, pandemics have forced humans to break with the past and imagine their world anew. This one is no different. It is a portal, a gateway between one world and the next. We can choose to walk through it, dragging the carcasses of our prejudice and hatred, our avarice, our data banks and dead ideas, our dead rivers and smoky skies behind us. Or we can walk through lightly, with little luggage, ready to imagine another world. And ready to fight for it'[627].

Appendix

The High Level Panel for a Sustainable Ocean Economy's products used in each respective report section

This report draws extensively—and occasionally quotes directly from—the initiative's 16 Blue Papers and 3 special reports—'The Ocean as a Solution to Climate Change', 'A Sustainable Ocean Economy for 2050—Approximating Its Benefits and Costs' and 'A Sustainable and Equitable Blue Recovery to the COVID-19 Crisis'—with the permission of the authors. The figure below shows the report sections in which the special report and respective Blue Papers are used.

REPORT SECTION	BLUE PAPER / OSCC REPORT
Chapter 1. The Urgency of Today	
A Blue Awakening: Recognising That the Ocean Is Vital to Humankind and the Global Economy	1,3,8,10
Failing the Environment and the People: The Need for Urgent Action	1,3,8,9,10,15,16,17
Embracing Hope: The Building Momentum for a Sustainable Ocean Economy	1,2,3,4,5,8,10,11,14,15,18,19
Chapter 2. The Possibility of Tomorrow	
Defining a Compass Direction: Principles for a Sustainable Ocean Economy	1,6,9,11,14
A New Picture Is Emerging: The 2050 Sustainable Ocean Economy	1,2,3,4,5,7,10,12,18
The Big Reconciliation: Protect Effectively, Produce Sustainably and Prosper Equitably	1,2,3,8,9,12,13,16,17
Chapter 3. A Roadmap to a Sustainable Ocean Economy	
Harnessing Complex Adaptive Systems: Lessons for the Sea	6
Charting a Direction: The Ocean Action Agenda	1,2,4,5,8,10,14,15,16,18,19
Launching the Voyage: Three Levels for Possible Immediate Action	6,17

The official Blue Paper and Special Report titles affiliated with the referenced numbers above are as follows:

1 The Ocean as a Solution to Climate Change: Five Opportunities for Action
2 The Future of Food from the Sea
3 The Expected Impacts of Climate Change on the Ocean Economy
4 Technology, Data and New Models for Sustainably Managing Ocean Resources
5 Illegal, Unreported and Unregulated Fishing and Associated Drivers
6 Towards Ocean Equity
7 The Ocean Genome: Conservation and the Fair, Equitable and Sustainable Use of Marine Genetic Resources
8 Critical Habitats and Biodiversity: Inventory, Thresholds and Governance
9 Integrated Ocean Management
10 Leveraging Multi-target Strategies to Address Plastic Pollution in the Context of an Already Stressed Ocean
11 The Ocean Transition: What to Learn from System Transitions
12 What Role for Ocean-Based Renewable Energy and Deep-Seabed Minerals in a Sustainable Future?
13 A Sustainable Ocean Economy for 2050: Approximating Its Benefits and Costs
14 National Accounting for the Ocean and Ocean Economy
15 Organised Crime in the Fisheries Sector
16 The Human Relationship with Our Ocean Planet
17 A Sustainable and Equitable Blue Recovery to the COVID-19 Crisis
18 Ocean Finance
19 Coastal Development: Managing Resilience, Restoration and Infrastructure of Coastlines

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Endnotes

1. UN Atlas of the Oceans. n.d. “Human Settlements on the Coast.” http://www.oceansatlas.org/subtopic/en/c/114/. Accessed 13 August 2020.
2. National Oceanic and Atmospheric Administration (NOAA). n.d. “How Much Oxygen Comes from the Ocean?” https://oceanservice.noaa.gov/facts/ocean-oxygen.html. Accessed 13 May 2020.
3. Olmer, N., B. Comer, B. Roy, X. Mao and D. Rutherford. 2017. “Greenhouse Gas Emissions from Global Shipping, 2013–2015.” Washington, DC: International Council on Clean Transport. https://theicct.org/sites/default/files/publications/Global-shipping-GHG-emissions-2013-2015_ICCT-Report_17102017_vF.pdf; International Chamber of Shipping. n.d. “Shipping and World Trade.” Accessed 18 August 2020. https://www.ics-shipping.org/shipping-facts/shipping-and-world-trade.
4. Teh, L.C.L., and U.R. Sumaila. 2013. “Contribution of Marine Fisheries to Worldwide Employment.” *Fish and Fisheries* 14 (1): 77–88. doi:10.1111/j.1467-2979.2011.00450.x.
5. OECD. 2016. *The Ocean Economy in 2030*. Report. Paris: OECD Publishing. https://www.oecd.org/environment/the-ocean-economy-in-2030-9789264251724-en.htm.
6. Costello, C., L. Cao, S. Gelcich et al. 2019. “The Future of Food from the Sea.” Washington, DC: World Resources Institute. https://www.oceanpanel.org/blue-papers/future-food-sea; IEA and ETP. 2017. “International Energy Agency, Energy Technology Perspectives 2017.” www.iea.org/etp2017.
7. Hoegh-Guldberg, O., et al. 2019. “The Ocean as a Solution to Climate Change: Five Opportunities for Action.” Washington, DC: World Resources Institute. https://oceanpanel.org/sites/default/files/2019-10/HLP_Report_Ocean_Solution_Climate_Change_final.pdf.
8. Konar, M., and H. Ding. 2020. “A Sustainable Ocean Economy for 2050: Approximating Its Benefits and Costs.” Washington, DC: World Resources Institute. https://www.oceanpanel.org/Economicanalysis.
9. Stocker, T.F., D. Qin, G.K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels et al. 2013. “Summary for Policymakers.” In *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press. http://www.climatechange2013.org/images/report/WG1AR5_SPM_FINAL.pdf; National Oceanic and Atmospheric Administration (NOAA). n.d. “How Much Oxygen Comes from the Ocean?” https://oceanservice.noaa.gov/facts/ocean-oxygen.html. Accessed 13 May 2020.
10. Hoegh-Guldberg et al. 2019. “The Ocean as a Solution to Climate Change.”
11. Olmer, N., B. Comer, B. Roy, X. Mao and D. Rutherford. 2017. “Greenhouse Gas Emissions from Global Shipping, 2013–2015”; International Chamber of Shipping. n.d. “Shipping and World Trade."
12. OECD. 2016. *The Ocean Economy in 2030*.
13. Teh, L.C.L., and U.R. Sumaila. 2013. “Contribution of Marine Fisheries to Worldwide Employment.”
14. FAO, ed. 2018. The State of World Fisheries and Aquaculture 2018: Meeting the Sustainable Development Goals. Rome: Food and Agriculture Organization of the United Nations. http://www.fao.org/3/I9540EN/i9540en.pdf; World Health Organization. n.d. “3. Global and Regional Food Consumption Patterns and Trends.” https://www.who.int/nutrition/topics/3_foodconsumption/en/index2.html. Accessed 6 May 2020.
15. Masson-Delmotte, V., P. Zhai, H.O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani et al., eds. 2019. *Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf.
16. Allison, E., J. Kurien and Y. Ota. 2020. “The Human Relationship with Our Ocean Planet.” Washington, DC: World Resources Institute. https://www.oceanpanel.org/blue-papers/relationship-between-humans-and-their-ocean-planet.
17. Kulp, S.A., and B.H. Strauss. 2019. “New Elevation Data Triple Estimates of Global Vulnerability to Sea-Level Rise and Coastal Flooding.” *Nature Communications* 10 (1): 4844. doi:10.1038/s41467-019-12808-z.
18. Pachauri, R.K., L. Mayer and Intergovernmental Panel on Climate Change, eds. 2015. *Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change 2014: Synthesis Report*. Geneva: Intergovernmental Panel on Climate Change. https://ar5-syr.ipcc.ch/ipcc/ipcc/resources/pdf/IPCC_SynthesisReport.pdf.
19. Nicholls, M. 2014. “Climate Change: Implications for Tourism: Key Findings from the Intergovernmental Panel on Climate Change Fifth Assessment Report.” University of Cambridge. https://www.cisl.cam.ac.uk/business-action/low-carbon-transformation/ipcc-climate-science-business-briefings/pdfs/briefings/ipcc-ar5-implications-for-tourism-briefing-prin.pdf.
20. Polidoro, B.A., K.E. Carpenter, L. Collins, N.C. Duke, A.M. Ellison, J.C. Ellison, E.J. Farnsworth et al. 2010. “The Loss of Species: Mangrove Extinction Risk and Geographic Areas of Global Concern.” Edited by D.M. Hansen. *PLOS ONE* 5 (4): e10095. doi:10.1371/journal.pone.0010095; Valiela, I., J.L. Bowen and J.K. York. 2001. “Mangrove Forests: One of the World’s Threatened Major Tropical Environments. At Least 35% of the Area of Mangrove Forests Has Been Lost in the Past Two Decades, Losses That Exceed Those for Tropical Rain Forests and Coral Reefs, Two Other Well-Known Threatened Environments.” *BioScience* 51 (10): 807–15. doi:10.1641/0006-3568(2001)051[0807:MFOOTW]2.0.CO;2; Thomas, N., R. Lucas, P. Bunting, A. Hardy, A. Rosenqvist and M. Simard. 2017. “Distribution and Drivers of Global Mangrove Forest Change, 1996–2010.” Edited by S. Joseph. *PLOS ONE* 12 (6): e0179302. doi:10.1371/journal.pone.0179302.
21. Díaz et al. 2019. “Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.”
22. Masson-Delmotte et al. 2019. *Global Warming of 1.5°C*.
23. Worm, B., M. Sandow, A. Oschlies, H.K. Lotze and R.A. Myers. 2005. “Global Patterns of Predator Diversity in the Open Oceans.” *Science* 309 (5739): 1365–69. doi:10.1126/science.1113399.
24. Gaines, S., R. Cabral, C.M. Free, Y. Golbuu, R. Arnason, W. Battista, D. Bradley et al. 2019. “The Expected Impacts of Climate Change on the Ocean Economy.” Washington, DC: World Resources Institute. https://www.oceanpanel.org/blue-papers/expected-impacts-climate-change-ocean-economy.
25. Ocean Conservancy. n.d. *Stemming the Tide: Land-Based Strategies for a Plastic-Free Ocean*. https://oceanconservancy.org/wp-content/uploads/2017/04/full-report-stemming-the.pdf. Accessed 6 May 2020.
26. Gall, S.C., and R.C. Thompson. 2015. “The Impact of Debris on Marine Life.” *Marine Pollution Bulletin* 92 (1): 170–79. doi:10.1016/j.marpolbul.2014.12.041.

27. Global Environment Facility–UN Development Programme–International Maritime Organization (GEF-UNDP-IMO) GloBallast Partnerships Programme and International Union for Conservation of Nature (IUCN). 2010. “Economic Assessments for Ballast Water Management: A Guideline.” GloBallast Monograph Series no. 19. London, UK, and Gland, Switzerland: GEF-UNDP-IMO GloBallast Partnerships, IUCN. https://portals.iucn.org/library/sites/library/files/documents/2010-075.pdf.

28. Rogers, A., O. Aburto-Oropeza, W. Appeltans, J. Assis, L. T. Ballance, P. Cury, C. Duarte et al. 2020. “Critical Habitats and Biodiversity: Inventory, Thresholds and Governance.” Washington, DC: World Resources Institute. https://www.oceanpanel.org/blue-papers/critical-habitats-and-biodiversity-inventory-thresholds-and-governance.

29. Costello et al. 2019. “The Future of Food from the Sea.”

30. Pörtner, H.O., D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, K. Poloczanska, K. Mintenbeck et al., eds. 2019. “Summary for Policymakers.” In *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*. Intergovernmental Panel on Climate Change. https://report.ipcc.ch/srocc/pdf/SROCC_FinalDraft_FullReport.pdf.

31. Hoegh-Guldberg, O., et al. 2019. “The Ocean as a Solution to Climate Change: Five Opportunities for Action.”

32. Ferrario, F., M.W. Beck, C.D. Storlazzi, F. Micheli, C.C. Shepard and L. Airoldi. 2014. “The Effectiveness of Coral Reefs for Coastal Hazard Risk Reduction and Adaptation.” *Nature Communications* 5 (1): 3794. doi:10.1038/ncomms4794.

33. da Silva, I.M., N. Hill, H. Shimadzu, A.M.V.M. Soares and M. Dornelas. 2015. “Spillover Effects of a Community-Managed Marine Reserve.” *PLOS ONE* 10 (4): e0111774. doi:10.1371/journal.pone.0111774.

34. Costello et al. 2019. “The Future of Food from the Sea.”

35. Costello et al. 2019. “The Future of Food from the Sea.”

36. Costello et al. 2019. “The Future of Food from the Sea.”

37. FAO. 2017. “FAO Regional Office for Europe and Central Asia: Losses in Fisheries and Aquaculture Tackled at Global Fishery Forum.” 14 September. http://www.fao.org/europe/news/detail-news/en/c/1037271/.

38. IEA. n.d. “Data & Statistics”; Haugan et al. 2019. “What Role for Ocean-Based Renewable Energy and Deep-Seabed Minerals in a Sustainable Future?”

39. Konar and Ding. 2020. “A Sustainable Ocean Economy for 2050.”

40. IMO. n.d. “Women in Maritime: IMO’s Gender Programme.” http://www.imo.org/en/OurWork/TechnicalCooperation/Pages/WomenInMaritime.aspx. Accessed 11 May 2020.

41. OECD. 2016. *The Ocean Economy in 2030*. Directorate for Science, Technology and Innovation Policy Note, April. https://www.oecd.org/futures/Policy-Note-Ocean-Economy.pdf.

42. Swilling, M., M. Ruckelshaus, T.B. Rudolph, P. Mbatha, E. Allison, S. Gelcich and H. Österblom. 2020. “The Ocean Transition: What to Learn from System Transitions.” Washington, DC: World Resources Institute. https://www.oceanpanel.org/blue-papers/ocean-transition-what-learn-system-transitions.

43. Costello, C., D. Ovando, T. Clavelle, C.K. Strauss, R. Hilborn, M.C. Melnychuk, T.A. Branch et al. 2016. “Global Fishery Prospects under Contrasting Management Regimes.” *Proceedings of the National Academy of Sciences* 113 (18): 5125–29. doi:10.1073/pnas.1520420113.

44. Widjaja, S., T. Long, H. Wirajuda, A. Gusman, S. Juwana, T. Ruchimat and C. Wilcox. 2020. “Illegal, Unreported and Unregulated Fishing and Associated Drivers.” Washington, DC: World Resources Institute. https://oceanpanel.org/sites/default/files/2020-02/HLP%20Blue%20Paper%20on%20IUU%20Fishing%20and%20Associated%20Drivers.pdf; Witbooi et al. 2020. “Organized Crime in the Fisheries Sector.”

45. Inniss, L., A. Simcock, A.Y. Ajawin, A.C. Alcala, P. Bernal, H.P. Calumpong, P.E. Araghi et al. 2016. “The First Global Integrated Marine Assessment.” New York: United Nations. https://www.un.org/Depts/los/global_reporting/WOA_RPROC/WOACompilation.pdf.

46. Northrop, E., M. Konar, N. Frost and E. Hollaway. 2020. “A Sustainable and Equitable Blue Recovery to the COVID-19 Crisis.” Washington, DC: World Resources Institute.

47. Nyborg, K., J.M. Anderies, A. Dannenberg, T. Lindahl, C. Schill, M. Schlüter, W.N. Adger et al. 2016. “Social Norms as Solutions.” *Science* 354 (6308): 42–43. doi:10.1126/science.aaf8317; Leape et al. 2020. “Technology, Data and New Models for Sustainably Managing Ocean Resources.”

48. Bailey, R.M., E. Carrella, R. Axtell, M.G. Burgess, R.B. Cabral, M. Drexler, C. Dorsett et al. 2019. “A Computational Approach to Managing Coupled Human-Environmental Systems: The POSEIDON Model of Ocean Fisheries.” *Sustainability Science* 14 (2): 259–75. doi:10.1007/s11625-018-0579-9.

49. OECD. 2019. *Rethinking Innovation for a Sustainable Ocean Economy*. Paris: Organisation for Economic Co-operation and Development. doi:10.1787/9789264311053-en.

50. Costello, C., S.D. Gaines and J. Lynham. 2008. “Can Catch Shares Prevent Fisheries Collapse?” *Science* 321 (5896): 1678–81. doi:10.1126/science.1159478.

51. Peng, B., H. Hong, X. Xue and D. Jin. 2006. “On the Measurement of Socioeconomic Benefits of Integrated Coastal Management (ICM): Application to Xiamen, China.” *Ocean & Coastal Management* 49 (3): 93–109. doi:10.1016/j.ocecoaman.2006.02.002.

52. Sumaila, U.R., C.M. Rodriguez, M. Schultz, R. Sharma, T.D. Tyrrell, H. Masundire, A. Damodaran et al. 2017. “Investments to Reverse Biodiversity Loss Are Economically Beneficial.” *Current Opinion in Environmental Sustainability* 29 (December): 82–88. doi:10.1016/j.cosust.2018.01.007.

53. Lau et al. 2020. “Evaluating Scenarios toward Zero Plastic Pollution”; Pew Charitable Trusts and SYSTEMIQ. 2020. *Breaking the Plastic Wave*.

54. Reusch, T.B.H., J. Dierking, H.C. Andersson, E. Bonsdorff, J. Carstensen, M. Casini, M. Czajkowski et al. 2018. “The Baltic Sea as a Time Machine for the Future Coastal Ocean.” *Science Advances* 4 (5): eaar8195. doi:10.1126/sciadv.aar8195.

55. Responsible Investor Research and Credit Suisse. 2020. *Investors and the Blue Economy*. https://www.esg-data.com/reports.

56. Ouyang, Z., C. Song, H. Zheng, S. Polasky, Y. Xiao, I. Bateman, J. Liu et al. 2020. “Using Gross Ecosystem Product (GEP) to Value Nature in Decision-Making.” https://ore.exeter.ac.uk/repository/handle/10871/120272.

57. Natural Resources Defense Council, Conservation Law Foundation, Earthjustice, Ocean Conservancy, Oceana and Pew Charitable Trusts. 2018. “How the Magnuson-Stevens Act Is Helping Rebuild U.S. Fisheries.” https://www.nrdc.org/sites/default/files/magnuson-stevens-act-rebuild-us-fisheries-fs.pdf.

58. Mikoko Pamoja Project. n.d. *ACES* (blog). https://www.aces-org.co.uk/mikoko-pamoja-project/. Accessed 5 May 2020.

59. Huxham, M. 2018. “MIKOKO PAMOJA: Mangrove Conservation for Community Benefit.” Mikoko Pamoja Team. Plan Vivo Project Design Document (PDD): 38.

60. Huff, A., and C. Tonui. 2017. *Making “Mangroves Together”: Carbon, Conservation and Co-management in Gazi Bay, Kenya*. ESRC STEPS Centre. https://opendocs.ids.ac.uk/opendocs/handle/20.500.12413/12970.

61. *MPA News*. 2020. “Funding MPAs by Selling Blue Carbon Credits: Practitioners from the First Projects Describe Their Experience So Far.” 30 July. https://mpanews.openchannels.org/news/mpa-news/funding-mpas-selling-blue-carbon-credits-practitioners-first-projects-describe-their.

62. Global Mangrove Alliance. 2019. “Mikoko Pamoja: A Business Case for Carbon Credit in Gazi-Kwale County, Kenya.” 8 May. http://www.mangrovealliance.org/mikoko-pamoja/.

63. Wylie, L., A.E. Sutton-Grier and A. Moore. 2016. "Keys to Successful Blue Carbon Projects: Lessons Learned from Global Case Studies." *Marine Policy* 65 (March): 76–84. doi:10.1016/j.marpol.2015.12.020.

64. Wylie et al. 2016. "Keys to Successful Blue Carbon Projects."

65. Mikoko Pamoja Project. n.d. Blog.

66. Garcia, S., Y. Ye, J. Rice and A. Charles. 2018. "Rebuilding of Marine Fisheries." Rome: Food and Agriculture Organization of the United Nations. http://www.fao.org/3/ca0161en/ca0161en.pdf.

67. All results received from personal communication with Rare Conservation.

68. Merino, G., F. Maynou and J. Boncoeur. 2009. "Bioeconomic Model for a Three-Zone Marine Protected Area: A Case Study of Medes Islands (Northwest Mediterranean)." *ICES Journal of Marine Science* 66 (1): 147–54. doi:10.1093/icesjms/fsn200.

69. Sala, E., C. Costello, J. de Bourbon Parme, M. Fiorese, G. Heal, K. Kelleher, R. Moffitt et al. 2016. "Fish Banks: An Economic Model to Scale Marine Conservation." *Marine Policy* 73 (November): 154–61. doi:10.1016/j.marpol.2016.07.032.

70. Bren, S. 2019. *Eat Like a Fish: My Adventures as a Fisherman Turned Restorative Ocean Farmer*. Sydney: Murdoch.

71. GreenWave. n.d. "Our Model." https://www.greenwave.org/our-model. Accessed 13 May 2020.

72. GreenWave. n.d. "Our Model."

73. Borken-Kleefeld, J., T. Berntsen and J. Fuglestvedt. 2010. "Specific Climate Impact of Passenger and Freight Transport." *Environmental Science & Technology* 44 (15): 5700–5706. doi:10.1021/es9039693.

74. International Maritime Organization (IMO). 2015. "Third IMO Greenhouse Gas Study 2014." London: IMO, 3. http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Documents/Third%20Greenhouse%20Gas%20Study/GHG3%20Executive%20Summary%20and%20Report.pdf.

75. Organisation for Economic Co-operation and Development (OECD). 2017. "ITF Transport Outlook 2017." Paris: OECD Publishing. https://www.oecd.org/about/publishing/itf-transport-outlook-2017-9789282108000-en.htm.

76. IMO. 2018. "UN Body Adopts Climate Change Strategy for Shipping." http://www.imo.org/en/MediaCentre/PressBriefings/Pages/06GHGinitialstrategy.aspx.

77. Rockström, J., W. Steffen, K. Noone, Å. Persson, F.S. Chapin, E. Lambin, T.M. Lenton et al. 2009. "Planetary Boundaries: Exploring the Safe Operating Space for Humanity." *Ecology and Society* 14 (2). https://www.jstor.org/stable/26268316.

78. Hoegh-Guldberg, O., et al. 2019. "The Ocean as a Solution to Climate Change: Five Opportunities for Action." Washington, DC: World Resources Institute. https://oceanpanel.org/sites/default/files/2019-10/HLP_Report_Ocean_Solution_Climate_Change_final.pdf.

79. Kantar, David. 2020. "Perceptions of the Ocean and Environment." Lucile Packard Foundation. https://oursharedseas.com/wp-content/uploads/2020/03/Packard-Kantar-Ocean-Report-FINAL-1.pdf.

80. Park, K.S., and D.J. Kildow. 2014. "Rebuilding the Classification System of the Ocean Economy." *Journal of Ocean and Coastal Economics*, no. 1. doi:10.15351/2373-8456.1001.

81. OECD. 2016. "The Ocean Economy in 2030." Directorate for Science, Technology and Innovation Policy Note, April. https://www.oecd.org/futures/Policy-Note-Ocean-Economy.pdf.

82. OECD. 2016. *The Ocean Economy in 2030*. Report. Paris: OECD Publishing. https://www.oecd.org/environment/the-ocean-economy-in-2030-9789264251724-en.htm.

83. Hoegh-Guldberg, O., and Boston Consulting Group. 2015. "Reviving the Ocean Economy: The Case for Action—2015." Geneva: WWF International.

84. OECD. 2016. "The Ocean Economy in 2030." Directorate for Science, Technology and Innovation Policy Note, April. https://www.oecd.org/futures/Policy-Note-Ocean-Economy.pdf.

85. Teh, L.C.L., and U.R. Sumaila. 2013. "Contribution of Marine Fisheries to Worldwide Employment." *Fish and Fisheries* 14 (1): 77–88. doi:10.1111/j.1467-2979.2011.00450.x.

86. World Bank and UN Department of Economic and Social Affairs. 2017. "The Potential of the Blue Economy: Increasing Long-Term Benefits of the Sustainable Use of Marine Resources for Small Island Developing States and Coastal Least Developed Countries." Washington, DC: World Bank. https://openknowledge.worldbank.org/bitstream/handle/10986/26843/115545.pdf?sequence=1&isAllowed=y.

87. National Oceanic and Atmospheric Administration (NOAA). n.d. "How Much Oxygen Comes from the Ocean?" https://oceanservice.noaa.gov/facts/ocean-oxygen.html. Accessed 13 May 2020.

88. Allison, E., J. Kurien and Y. Ota. 2020. "The Human Relationship with Our Ocean Planet." Washington, DC: World Resources Institute. https://www.oceanpanel.org/blue-papers/relationship-between-humans-and-their-ocean-planet.

89. Millennium Ecosystem Assessment (Program), ed. 2005. *Ecosystems and Human Well-Being: Synthesis*. Washington, DC: Island.

90. Díaz, S., J. Settele, E.S. Brondízio, H.T. Ngo, M. Guèze, J. Agard, A. Arneth et al. 2019. "Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services." Bonn, Germany: Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. doi:10.5281/zenodo.3553579.

91. Díaz et al. 2019. "Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services."

92. FAO Fisheries and Aquaculture Department. n.d. "Small-Scale Fisheries around the World." Food and Agriculture Organization of the United Nations. http://www.fao.org/fishery/ssf/world/en. Accessed 6 May 2020.

93. World Health Organization. n.d. "3. Global and Regional Food Consumption Patterns and Trends." https://www.who.int/nutrition/topics/3_foodconsumption/en/index2.html. Accessed 6 May 2020.

94. Pörtner, H.O., D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, K. Poloczanska, K. Mintenbeck et al., eds. 2019. "Summary for Policymakers." In *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*. Intergovernmental Panel on Climate Change. https://report.ipcc.ch/srocc/pdf/SROCC_FinalDraft_FullReport.pdf.

95. NOAA. n.d. "How Much Oxygen Comes from the Ocean?"

96. UN Atlas of the Oceans. n.d. "Human Settlements on the Coast." http://www.oceansatlas.org/subtopic/en/c/114/. Accessed 13 August 2020.

97. Olmer, N., B. Comer, B. Roy, X. Mao and D. Rutherford. 2017. "Greenhouse Gas Emissions from Global Shipping, 2013–2015." Washington, DC: International Council on Clean Transport. https://theicct.org/sites/default/files/publications/Global-shipping-GHG-emissions-2013-2015_ICCT-Report_17102017_vF.pdf; International Chamber of Shipping. n.d. "Shipping and World Trade."

98. UN Department of Economic and Social Affairs. n.d. "2019 Revision of World Population Prospects." https://population.un.org/wpp/. Accessed 6 May 2020; Vollset, S.E., E. Goren, C.-W. Yuan, J. Cao, A.E. Smith, T. Hsiao, C. Bisignano et al. 2020. "Fertility, Mortality, Migration, and Population Scenarios for 195 Countries and Territories from 2017 to 2100: A Forecasting Analysis for the Global Burden of Disease Study." *Lancet*, 14 July. doi:10.1016/S0140-6736(20)30677-2.

99. Food and Agriculture Organization of the United Nations (FAO). n.d. "How to Feed the World in 2050." http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf. Accessed 6 May 2020.

100. Hoegh-Guldberg et al. 2019. "The Ocean as a Solution to Climate Change."

101. Willett, W., J. Rockström, B. Loken, M. Springmann, T. Lang, S. Vermeulen, T. Garnett et al. 2019. "Food in the Anthropocene: The EAT–Lancet Commission on Healthy Diets from Sustainable Food Systems." *Lancet* 393 (10170): 447–92. doi:10.1016/S0140-6736(18)31788-4. This report cites a required increase of about 55 percent to 125 percent of fish and seafood production in 2050. We chose the halfway point within this range, 90 percent, and applied it to the seafood production stated in Costello, C., L. Cao, S. Gelcich et al. 2019. "The Future of Food from the Sea." Washington, DC: World Resources Institute. https://www.oceanpanel.org/blue-papers/future-food-sea.

102. Troell, M., M. Jonell and B. Crona. 2019. "The Role of Seafood in Sustainable and Healthy Diets." EAT-Lancet Commission, 24. https://eatforum.org/content/uploads/2019/11/Seafood_Scoping_Report_EAT-Lancet.pdf.

103. Troell et al. 2019. "The Role of Seafood in Sustainable and Healthy Diets," 24.

104. Costello et al. 2019. "The Future of Food from the Sea."

105. Costello et al. 2019. "The Future of Food from the Sea."

106. Costello et al. 2019. "The Future of Food from the Sea."

107. Costello et al. 2019. "The Future of Food from the Sea."

108. Kuttschreuter, M. 2006. "Psychological Determinants of Reactions to Food Risk Messages." *Risk Analysis* 26 (4): 1045–57. doi:10.1111/j.1539-6924.2006.00799.x.

109. Allison et al. 2020. "The Human Relationship with Our Ocean Planet."

110. Masson-Delmotte, V., P. Zhai, H.O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani et al., eds. 2019. *Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf.

111. Hoegh-Guldberg et al. 2019. "The Ocean as a Solution to Climate Change."

112. Gallo, N.D., D.G. Victor and L.A. Levin. 2017. "Ocean Commitments under the Paris Agreement." *Nature Climate Change* 7 (11): 833–38. doi:10.1038/nclimate3422; Hoegh-Guldberg, O., E. Northrop and J. Lubchenco. 2019. "The Ocean Is Key to Achieving Climate and Societal Goals." *Science* 365 (6460): 1372–74. doi:10.1126/science.aaz4390.

113. International Energy Agency (IEA). 2019. *Offshore Wind Outlook 2019*. https://www.iea.org/reports/offshore-wind-outlook-2019.

114. Hamilton, S.E., and D. Casey. 2016. "Creation of a High Spatio-temporal Resolution Global Database of Continuous Mangrove Forest Cover for the 21st Century (CGMFC-21)." *Global Ecology and Biogeography* 25 (6): 729–38. doi:10.1111/geb.12449.

115. Duarte, C.M., ed. 2009. *Global Loss of Coastal Habitats: Rates, Causes and Consequences*. Bilbao, Spain: Fundación BBVA.

116. Duarte, C.M., W.C. Dennison, R.J.W. Orth and T.J.B. Carruthers. 2008. "The Charisma of Coastal Ecosystems: Addressing the Imbalance." *Estuaries and Coasts* 31 (2): 233–38. doi:10.1007/s12237-008-9038-7.

117. Neate, R. 2012. "Anchovy Price Leap Causes Food Industry Chain Reaction." *The Guardian*, 24 August. https://www.theguardian.com/business/2012/aug/24/anchovy-price-leap-food-industry-chain.

118. Ocean Conservancy. n.d. *Stemming the Tide: Land-Based Strategies for a Plastic-Free Ocean*. https://oceanconservancy.org/wp-content/uploads/2017/04/full-report-stemming-the.pdf. Accessed 6 May 2020.

119. 62 Core Writing Team, R.K. Pachauri and L. Meyer. 2014. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva: Intergovernmental Panel on Climate Change. https://www.ipcc.ch/site/assets/uploads/2018/05/SYR_AR5_FINAL_full_wcover.pdf.

120. Gattuso, J.-P., A. Magnan, R. Billé, W.W.L. Cheung, E.L. Howes, F. Joos, D. Allemand et al. 2015. "Contrasting Futures for Ocean and Society from Different Anthropogenic CO_2 Emissions Scenarios." *Science* 349 (6243). doi:10.1126/science.aac4722.

121. Lau et al. 2020. "Evaluating Scenarios toward Zero Plastic Pollution"; Pew Charitable Trusts and SYSTEMIQ. 2020. *Breaking the Plastic Wave*. https://www.systemiq.earth/wp-content/uploads/2020/07/BreakingThePlasticWave_MainReport.pdf.

122. UN Statistics Division. n.d. "Goal 14: Conserve and Sustainably Use the Oceans, Seas and Marine Resources for Sustainable Development: SDG Indicators." Development Data and Outreach. https://unstats.un.org/sdgs/report/2017/goal-14/. Accessed 6 May 2020.

123. Definition of Circular Economy by Ellen MacArthur Foundation: A circular economy is based on the principles of designing out waste and pollution, keeping products and materials in use and regenerating natural systems.

124. Dalberg Advisors. 2019. "Solving Plastic Pollution through Accountability." Gland, Switzerland: World Wide Fund For Nature. https://c402277.ssl.cf1.rackcdn.com/publications/1212/files/original/SOLVING_PLASTIC_POLLUTION_THROUGH_ACCOUNTABILITY_ENF_SINGLE.pdf?1551798060.

125. Jouffray, J.-B., R. Blasiak, A.V. Norström, H. Österblom and M. Nyström. 2020. "The Blue Acceleration: The Trajectory of Human Expansion into the Ocean." *One Earth* 2 (1): 43–54. doi:10.1016/j.oneear.2019.12.016.

126. Díaz et al. 2019. "Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services."

127. Jones, K.R., C.J. Klein, B.S. Halpern, O. Venter, H. Grantham, C.D. Kuempel, N. Shumway et al. 2018. "The Location and Protection Status of Earth's Diminishing Marine Wilderness." *Current Biology* 28 (15): 2506–12.e3. doi:10.1016/j.cub.2018.06.010.

128. Halpern, B.S., M. Frazier, J. Potapenko, K.S. Casey, K. Koenig, C. Longo, J.S. Lowndes et al. 2015. "Spatial and Temporal Changes in Cumulative Human Impacts on the World's Ocean." *Nature Communications* 6 (1): 1–7. doi:10.1038/ncomms8615.

129. Rogers, A., O. Aburto-Oropeza, W. Appeltans, J. Assis, L. T. Ballance, P. Cury, C. Duarte et al. 2020. "Critical Habitats and Biodiversity: Inventory, Thresholds and Governance." Washington, DC: World Resources Institute. https://www.oceanpanel.org/blue-papers/critical-habitats-and-biodiversity-inventory-thresholds-and-governance.

130. 73 Díaz et al. 2019. "Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services."

131. Rogers et al. 2020. "Critical Habitats and Biodiversity."

132. FAO, ed. 2018. *The State of World Fisheries and Aquaculture 2018: Meeting the Sustainable Development Goals*. Rome: Food and Agriculture Organization of the United Nations. http://www.fao.org/3/I9540EN/i9540en.pdf.

133. Pauly, D., D. Zeller and M.L.D. Palomares. n.d. "Sea around Us Concepts, Design and Data." http://www.seaaroundus.org. Accessed 6 May 2020.

134. Roff, G., C.J. Brown, M.A. Priest and P.J. Mumby. 2018. "Decline of Coastal Apex Shark Populations over the Past Half Century." *Communications Biology* 1 (1): 1–11. doi:10.1038/s42003-018-0233-1; Christensen, V., M. Coll, C. Piroddi, J. Steenbeek, J. Buszowski and D. Pauly. 2014. "A Century of Fish Biomass Decline in the Ocean." *Marine Ecology Progress Series* 512 (October): 155–66. doi:10.3354/meps10946.

135. MacNeil, M.A., D.D. Chapman, M. Heupel, C.A. Simpfendorfer, M. Heithaus, M. Meekan, E. Harvey et al. 2020. "Global Status and Conservation Potential of Reef Sharks." *Nature* 583 (7818): 801–6. doi:10.1038/s41586-020-2519-y.

136. Worm, B., M. Sandow, A. Oschlies, H.K. Lotze and R.A. Myers. 2005. "Global Patterns of Predator Diversity in the Open Oceans." *Science* 309 (5739): 1365–69. doi:10.1126/science.1113399.

137. Stocker, T.F., D. Qin, G.K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels et al. 2013. "Summary for Policymakers." In *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press. http://www.climatechange2013.org/images/report/WG1AR5_SPM_FINAL.pdf.

138. Laffoley, D., and J.M. Baxter, eds. 2016. *Explaining Ocean Warming: Causes, Scale, Effects and Consequences*. International Union for Conservation of Nature. doi:10.2305/IUCN.CH.2016.08.en.

139. Cheng, L., J. Abraham, J. Zhu, K.E. Trenberth, J. Fasullo, T. Boyer, R. Locarnini et al. 2020. "Record-Setting Ocean Warmth Continued in 2019." *Advances in Atmospheric Sciences* 37 (2): 137–42. doi:10.1007/s00376-020-9283-7.

140. National Snow and Ice Data Center. 2018. "Arctic Sea Ice Extent Arrives at Its Minimum." Arctic Sea Ice News and Analysis (blog). http://nsidc.org/arcticseaicenews/2018/09/arctic-sea-ice-extent-arrives-at-its-minimum/.

141. Gaines, S., R. Cabral, C.M. Free, Y. Golbuu, R. Arnason, W. Battista, D. Bradley et al. 2019. "The Expected Impacts of Climate Change on the Ocean Economy." Washington, DC: World Resources Institute. https://www.oceanpanel.org/blue-papers/expected-impacts-climate-change-ocean-economy.

142. Hu, S., J. Sprintall, C. Guan, M.J. McPhaden, F. Wang, D. Hu and W. Cai. 2020. "Deep-Reaching Acceleration of Global Mean Ocean Circulation over the Past Two Decades." *Science Advances* 6 (6): eaax7727. doi:10.1126/sciadv.aax7727.

143. Hu et al. 2020. "Deep-Reaching Acceleration of Global Mean Ocean Circulation over the Past Two Decades."

144. Palter, J.B. 2015. "The Role of the Gulf Stream in European Climate." *Annual Review of Marine Science* 7 (1): 113–37. doi:10.1146/annurev-marine-010814-015656.

145. Ramesh, N., J.A. Rising and K.L. Oremus. 2019. "The Small World of Global Marine Fisheries: The Cross-Boundary Consequences of Larval Dispersal." *Science* 364 (6446): 1192–96. doi:10.1126/science.aav3409.

146. Bakun, A., B.A. Black, S.J. Bograd, M. García-Reyes, A.J. Miller, R.R. Rykaczewski and W.J. Sydeman. 2015. "Anticipated Effects of Climate Change on Coastal Upwelling Ecosystems." *Current Climate Change Reports* 1 (2): 85–93. doi:10.1007/s40641-015-0008-4.

147. Collins, M., R. Knutti, J. Arblaster, J.-L. Dufresne, T. Fichefet, X. Gao, W.J. Gutowski Jr. et al. 2013. "Long-Term Climate Change: Projections, Commitments and Irreversibility." In *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press. https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter12_FINAL.pdf.

148. Collins et al. 2013. "Long-Term Climate Change."

149. Gaines et al. 2019. "The Expected Impacts of Climate Change on the Ocean Economy."

150. Polidoro, B.A., K.E. Carpenter, L. Collins, N.C. Duke, A.M. Ellison, J.C. Ellison, E.J. Farnsworth et al. 2010. "The Loss of Species: Mangrove Extinction Risk and Geographic Areas of Global Concern." Edited by D.M. Hansen. *PLOS ONE* 5 (4): e10095. doi:10.1371/journal.pone.0010095; Valiela, I., J.L. Bowen and J.K. York. 2001. "Mangrove Forests: One of the World's Threatened Major Tropical Environments. At Least 35% of the Area of Mangrove Forests Has Been Lost in the Past Two Decades, Losses That Exceed Those for Tropical Rain Forests and Coral Reefs, Two Other Well-Known Threatened Environments." *BioScience* 51 (10): 807–15. doi:10.1641/0006-3568(2001)051[0807:MFOOTW]2.0.CO;2; Thomas, N., R. Lucas, P. Bunting, A. Hardy, A. Rosenqvist and M. Simard. 2017. "Distribution and Drivers of Global Mangrove Forest Change, 1996–2010." Edited by S. Joseph. *PLOS ONE* 12 (6): e0179302. doi:10.1371/journal.pone.0179302.

151. Richards, D.R., and D.A. Friess. 2016. "Rates and Drivers of Mangrove Deforestation in Southeast Asia, 2000–2012." *Proceedings of the National Academy of Sciences* 113 (2): 344–49. doi:10.1073/pnas.1510272113.

152. Aburto-Oropeza, O., E. Ezcurra, G. Danemann, V. Valdez, J. Murray and E. Sala. 2008. "Mangroves in the Gulf of California Increase Fishery Yields." *Proceedings of the National Academy of Sciences* 105 (30): 10456–59. doi:10.1073/pnas.0804601105.

153. Nellemann, C., and E. Corcoran. 2009. *Blue Carbon: The Role of Healthy Oceans in Binding Carbon: A Rapid Response Assessment*. UN Environment Programme/Earthprint.

154. Duarte, C.M., H. Kennedy, N. Marbà and I. Hendriks. 2013. "Assessing the Capacity of Seagrass Meadows for Carbon Burial: Current Limitations and Future Strategies." *Ocean & Coastal Management* 83 (October): 32–38. doi:10.1016/j.ocecoaman.2011.09.001.

155. Inniss, L., A. Simcock, A.Y. Ajawin, A.C. Alcala, P. Bernal, H.P. Calumpong, P.E. Araghi et al. 2016. "The First Global Integrated Marine Assessment." New York: United Nations. https://www.un.org/Depts/los/global_reporting/WOA_RPROC/WOACompilation.pdf.

156. Beck, M.W., I.J. Losada, P. Menéndez, B.G. Reguero, P. Díaz-Simal and F. Fernández. 2018. "The Global Flood Protection Savings Provided by Coral Reefs." *Nature Communications* 9 (1): 1–9. doi:10.1038/s41467-018-04568-z.

157. Gall, S.C., and R.C. Thompson. 2015. "The Impact of Debris on Marine Life." *Marine Pollution Bulletin* 92 (1): 170–79. doi:10.1016/j.marpolbul.2014.12.041.

158. Lau, W.W.Y., Y. Shiran, R.M. Bailey, E. Cook, M.R. Stuchtey, J. Koskella, C.A. Velis et al. 2020. "Evaluating Scenarios toward Zero Plastic Pollution." *Science*, July. doi:10.1126/science.aba9475.

159. Lau et al. 2020. "Evaluating Scenarios toward Zero Plastic Pollution."

160. Law, K.L., and R.C. Thompson. 2014. "Microplastics in the Seas." *Science* 345 (6193): 144–45. doi:10.1126/science.1254065.

161. Jambeck, J., E. Moss, B.K. Dubey, Z. Arifin, L. Godfrey, B.D. Hardesty, G. Hendrawan et al. 2020. "Leveraging Multi-target Strategies to Address Plastic Pollution in the Context of an Already Stressed Ocean." Washington, DC: World Resources Institute. https://www.oceanpanel.org/blue-papers/leveraging-target-strategies-to-address-plastic-pollution-in-the-context.

162. Jambeck et al. 2020. "Leveraging Multi-target Strategies to Address Plastic Pollution in the Context of an Already Stressed Ocean."

163. Jambeck et al. 2020. "Leveraging Multi-target Strategies to Address Plastic Pollution in the Context of an Already Stressed Ocean"; Mills, L.J., and C. Chichester. 2005. "Review of Evidence: Are Endocrine-Disrupting Chemicals in the Aquatic Environment Impacting Fish Populations?" *Science of the Total Environment* 343 (1): 1–34. doi:10.1016/j.scitotenv.2004.12.070.

164. Global Environment Facility–UN Development Programme–International Maritime Organization (GEF-UNDP-IMO) GloBallast Partnerships Programme and International Union for Conservation of Nature (IUCN). 2010. "Economic Assessments for Ballast Water Management: A Guideline." GloBallast Monograph Series no. 19. London, UK, and Gland, Switzerland: GEF-UNDP-IMO GloBallast Partnerships, IUCN. https://portals.iucn.org/library/sites/library/files/documents/2010-075.pdf.

165. GEF-UNDP-IMO GloBallast Partnerships and International Ocean Institute (IOI). 2009. "Guidelines for National Ballast Water Status Assessment." GloBallast Monograph Series no. 17. https://archive.iwlearn.net/globallast.imo.org/wp-content/uploads/2014/11/Mono17_English.pdf.

166. Subba Rao, D.V., W.G. Sprules, H. Locke and J.T. Carlton. 1994. "Exotic Phytoplankton from Ship's Ballast Waters: Risk of Potential Spread to Mariculture Sites on Canada's East Coast." *Canadian Data Report of Fisheries and Aquatic Sciences*, no. 937: 1–51.

167. GEF-UNDP-IMO GloBallast Partnerships. 2017. "The GloBallast Story: Reflections from a Global Family." GloBallast Monograph no. 25. http://www.imo.org/en/MediaCentre/HotTopics/BWM/Documents/The%20GloBallast%20Story.pdf.

168. GEF-UNDP-IMO GloBallast Partnerships. 2017. "The GloBallast Story."

169. Jackson, E.J., M. Donovan, K. Cramer and V. Lam. 2014. "Status and Trends of Caribbean Coral Reefs: 1970–2012." Gland, Switzerland: Global Coral Reef Monitoring Network, International Union for Conservation of Nature.

170. Hughes, T.P.. J.T. Kerry, A.H. Baird, S.R. Connolly, A. Dietzel, C.M. Eakin, S.F. Heron et al. 2018. "Global Warming Transforms Coral Reef Assemblages." *Nature* 556: 492–96. https://doi.org/10.1038/s41586-018-0041-2.

171. van Hooidonk, R., J. Maynard, J. Tamelander, J. Gove, G. Ahmadia, L. Raymundo, G. Williams et al. 2016. "Local-Scale Projections of Coral Reef Futures and Implications of the Paris Agreement." *Scientific Reports* 6 (1): 1–8. doi:10.1038/srep39666.

172. Masson-Delmotte et al. 2019. *Global Warming of 1.5°C*.

173. Coles, S.L., K.D. Bahr, K.S. Rodgers, S.L. May, A.E. McGowan, A. Tsang, J. Bumgarner and J.H. Han. 2018. "Evidence of Acclimatization or Adaptation in Hawaiian Corals to Higher Ocean Temperatures." *PeerJ* 6 (August): e5347. doi:10.7717/peerj.5347.

174. Bay, R.A., N.H. Rose, C.A. Logan and S.R. Palumbi. 2017. "Genomic Models Predict Successful Coral Adaptation If Future Ocean Warming Rates Are Reduced." *Science Advances* 3 (11): e1701413. doi:10.1126/sciadv.1701413.

175. Inniss et al. 2016. "The First Global Integrated Marine Assessment."

176. Capotondi, A., M.A. Alexander, N.A. Bond, E.N. Curchitser and J.D. Scott. 2012. "Enhanced Upper Ocean Stratification with Climate Change in the CMIP3 Models." *Journal of Geophysical Research: Oceans* 117 (C4). doi:10.1029/2011JC007409.

177. Capotondi et al. 2012. "Enhanced Upper Ocean Stratification with Climate Change in the CMIP3 Models."

178. Capotondi et al. 2012. "Enhanced Upper Ocean Stratification with Climate Change in the CMIP3 Models."

179. Schmidtko, S., L. Stramma and M. Visbeck. 2017. "Decline in Global Oceanic Oxygen Content during the Past Five Decades." *Nature* 542 (7641): 335–39. doi:10.1038/nature21399.

180. Laffoley, D., and J.M. Baxter, eds. 2019. *Ocean Deoxygenation: Everyone's Problem—Causes, Impacts, Consequences and Solutions*. International Union for Conservation of Nature. doi:10.2305/IUCN.CH.2019.13.en; Long, M.C., C. Deutsch and T. Ito. 2016. "Finding Forced Trends in Oceanic Oxygen." *Global Biogeochemical Cycles* 30 (2): 381–97. doi:10.1002/2015GB005310; Keeling, R.F., A. Körtzinger and N. Gruber. 2010. "Ocean Deoxygenation in a Warming World." *Annual Review of Marine Science* 2 (1): 199–229. doi:10.1146/annurev.marine.010908.163855.

181. Breitburg, D., L.A. Levin, A. Oschlies, M. Grégoire, F.P. Chavez, D.J. Conley, V. Garçon et al. 2018. "Declining Oxygen in the Global Ocean and Coastal Waters." *Science* 359 (6371). doi:10.1126/science.aam7240.

182. Breitburg et al. 2018. "Declining Oxygen in the Global Ocean and Coastal Waters."

183. Keeling et al. 2010. "Ocean Deoxygenation in a Warming World."

184. Breitburg et al. 2018. "Declining Oxygen in the Global Ocean and Coastal Waters."

185. Laffoley and Baxter. 2019. *Ocean Deoxygenation*.

186. Laffoley and Baxter. 2019. *Ocean Deoxygenation*.

187. Díaz et al. 2019. "Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services."

188. Maureaud, A., D. Gascuel, M. Colléter, M.L.D. Palomares, H. Du Pontavice, D. Pauly and W.W.L. Cheung. 2017. "Global Change in the Trophic Functioning of Marine Food Webs." *PLOS ONE* 12 (8). doi:10.1371/journal.pone.0182826.

189. Christensen et al. 2014. "A Century of Fish Biomass Decline in the Ocean."

190. Gaines et al. 2019. "The Expected Impacts of Climate Change on the Ocean Economy."

191. Worm, B., E.B. Barbier, N. Beaumont, J.E. Duffy, C. Folke, B.S. Halpern, J.B.C. Jackson et al. 2006. "Impacts of Biodiversity Loss on Ocean Ecosystem Services." *Science* 314 (5800): 787–90. doi:10.1126/science.1132294.

192. Lindsey, R. 2019. "Climate Change: Global Sea Level." National Oceanic and Atmostpheric Administration, 14 August. https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level.

193. Sweet, W.V., R. Horton, R.E. Kopp, A.N. LeGrande and A. Romanou. 2017. "Sea Level Rise." In *Climate Science Special Report: Fourth National Climate Assessment*, vol. 1, edited by D.J. Wuebbles, D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart and T.K. Maycock, 333–63. Washington, DC: U.S. Global Change Research Program. doi: 10.7930/J0VM49F2.

194. Cazenave, A., B. Meyssignac and H. Palanisamy. 2018. "Global Sea Level Budget Assessment by World Climate Research Programme." Sea Scientific Data Open Edition (SEANOE). doi:10.17882/54854.

195. Church, J.A., P.U. Clark, A. Cazenave, J.M. Gregory, S. Jevrejeva, A. Levermann, M.A. Merrifield et al. 2013. "Sea Level Change." In *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by T.F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels et al. Cambridge: Cambridge University Press. https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter13_FINAL.pdf.

196. Bailey, R.M., and J.M.A. van der Grient. 2020. "OSIRIS: A Model for Integrating the Effects of Multiple Stressors on Marine Ecosystems." *Journal of Theoretical Biology* 493 (May): 110211. doi:10.1016/j.jtbi.2020.110211.
These models look at the ocean as a network of linked basic states (such as the populations of whales, or zooplankton, or temperature) and use large computer simulations to assess the impact of specific stressors on this network.

197. Bailey and van der Grient. 2020. "OSIRIS."

198. Pörtner et al. 2019. "Summary for Policymakers." In *Special Report on the Ocean and Cryosphere in a Changing Climate*.

199. Díaz et al. 2019. "Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services."

200. Gaines et al. 2019. "The Expected Impacts of Climate Change on the Ocean Economy."

201. Laffoley and Baxter. 2019. *Ocean Deoxygenation*.

202. Laffoley and Baxter. 2019. *Ocean Deoxygenation*.

203. Pinsky, M.L., G. Reygondeau, R. Caddell, J. Palacios-Abrantes, J. Spijkers and W.W.L. Cheung. 2018. "Preparing Ocean Governance for Species on the Move." *Science* 360 (6394): 1189–91. doi:10.1126/science.aat2360.

204. Gaines, S.D., C. Costello, B. Owashi, T. Mangin, J. Bone, J.G. Molinos, M. Burden et al. 2018. “Improved Fisheries Management Could Offset Many Negative Effects of Climate Change.” *Science Advances* 4 (8): eaao1378. doi:10.1126/sciadv.aao1378.

205. Garrett, A., and J. Pinnegar. 2019. “Climate Change Adaptation in the UK (Wild Capture) Seafood Industry 2018.” Seafish/Marine Climate Change Impacts Partnership. https://seafish.org/media/Publications/Climate_change_adaptation_in_the_UK_wild_capture_seafood_industry_2018.pdf.

206. Lubchenco, J., E.B. Cerny-Chipman, J.N. Reimer and S.A. Levin. 2016. “The Right Incentives Enable Ocean Sustainability Successes and Provide Hope for the Future.” *Proceedings of the National Academy of Sciences* 113 (51): 14507–14. doi:10.1073/pnas.1604982113.

207. Froehlich, H.E., R.R. Gentry and B.S. Halpern. 2018. “Global Change in Marine Aquaculture Production Potential under Climate Change.” *Nature Ecology & Evolution* 2 (11): 1745–50. doi:10.1038/s41559-018-0669-1.

208. Froehlich et al. 2018. “Global Change in Marine Aquaculture Production Potential under Climate Change.”

209. Rochman, C.M., A. Tahir, S.L. Williams, D.V. Baxa, R. Lam, J.T. Miller, F.-C. The et al. 2015. “Anthropogenic Debris in Seafood: Plastic Debris and Fibers from Textiles in Fish and Bivalves Sold for Human Consumption.” *Scientific Reports* 5 (1): 1–10. doi:10.1038/srep14340.

210. Phuong, N.N., L. Poirier, Q.T. Pham, F. Lagarde and A. Zalouk-Vergnoux. 2018. “Factors Influencing the Microplastic Contamination of Bivalves from the French Atlantic Coast: Location, Season and/or Mode of Life?” *Marine Pollution Bulletin* 129 (2): 664–74. doi:10.1016/j.marpolbul.2017.10.054; van Cauwenberghe, L., and C.R. Janssen. 2014. “Microplastics in Bivalves Cultured for Human Consumption.” *Environmental Pollution* 193 (October): 65–70. doi:10.1016/j.envpol.2014.06.010; Li, J., D. Yang, L. Li, K. Jabeen and H. Shi. 2015. “Microplastics in Commercial Bivalves from China.” *Environmental Pollution* 207 (December): 190–95. doi:10.1016/j.envpol.2015.09.018.

211. Nicholls, M. 2014. “Climate Change: Implications for Tourism: Key Findings from the Intergovernmental Panel on Climate Change Fifth Assessment Report.” University of Cambridge. https://www.cisl.cam.ac.uk/business-action/low-carbon-transformation/ipcc-climate-science-business-briefings/pdfs/briefings/ipcc-ar5-implications-for-tourism-briefing-prin.pdf.

212. Pachauri, R.K., L. Mayer and Intergovernmental Panel on Climate Change, eds. 2015. *Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change 2014: Synthesis Report*. Geneva: Intergovernmental Panel on Climate Change. https://ar5-syr.ipcc.ch/ipcc/ipcc/resources/pdf/IPCC_SynthesisReport.pdf.

213. Nicholls. 2014. “Climate Change.”

214. Nicholls. 2014. “Climate Change.”

215. Masson-Delmotte et al. 2019. *Global Warming of 1.5°C*.

216. Nicholls. 2014. “Climate Change.”

217. Diez, S.M., P.G. Patil, J. Morton, D.J. Rodriguez, A. Vanzella, D.V. Robin, T. Maes and C. Corbin. 2019. “Marine Pollution in the Caribbean: Not a Minute to Waste.” Washington, DC: World Bank Group. http://documents.worldbank.org/curated/en/482391554225185720/pdf/Marine-Pollution-in-the-Caribbean-Not-a-Minute-to-Waste.pdf.

218. Djakouré, S., M. Araujo, A. Hounsou-Gbo, C. Noriega and B. Bourlès. 2017. “On the Potential Causes of the Recent Pelagic Sargassum Blooms Events in the Tropical North Atlantic Ocean.” *Biogeosciences Discussions*, September, 1–20. doi:10.5194/bg-2017-346.

219. Agren, D. 2019. “Seaweed Invasion Threatens Tourism in Mexico’s Beaches as Problem Worsens.” *The Guardian*, 28 June. http://www.theguardian.com/world/2019/jun/28/mexico-seaweed-invasion-tourism-caribbean-beaches.

220. Coke-Hamilton, P. 2020. “Impact of COVID-19 on Tourism in Small Island Developing States.” UN Conference on Trade and Development. 24 April. https://unctad.org/en/pages/newsdetails.aspx?OriginalVersionID=2341.

221. Becker, A.H., M. Acciaro, R. Asariotis, E. Cabrera, L. Cretegny, P. Crist, M. Esteban et al. 2013. “A Note on Climate Change Adaptation for Seaports: A Challenge for Global Ports, a Challenge for Global Society.” *Climatic Change* 120 (4): 683–95. doi:10.1007/s10584-013-0843-z.

222. Becker et al. 2013. “A Note on Climate Change Adaptation for Seaports.”

223. Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea et al. 2012. *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press. https://www.ipcc.ch/site/assets/uploads/2018/03/SREX_Full_Report-1.pdf.

224. Tebaldi, C., B.H. Strauss and C.E. Zervas. 2012. “Modelling Sea Level Rise Impacts on Storm Surges along US Coasts.” *Environmental Research Letters* 7 (1): 014032. doi:10.1088/1748-9326/7/1/014032.

225. Becker et al. 2013. “A Note on Climate Change Adaptation for Seaports.”

226. Strauss, B.H., R.E. Kopp, W.V. Sweet and K. Bittermann. 2016. “Unnatural Coastal Floods: Sea Level Rise and the Human Fingerprint on U.S. Floods since 1950.” Princeton, NJ: Climate Central. https://sealevel.climatecentral.org/uploads/research/Unnatural-Coastal-Floods-2016.pdf.

227. Wong, P.P., I.J. Losada, J.P. Gattuso, J. Hinkel, A. Khattabi, M.L. McInnes, Y. Saito and A. Sallenger. n.d. “2014: Coastal Systems and Low-Lying Areas.” *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. Part A, *Global and Sectoral Aspects: Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by C.B. Field, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee et al. Cambridge: Cambridge University Press.

228. Díaz et al. 2019. “Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.”

229. Vousdoukas, M.I., L. Mentaschi, E. Voukouvalas, A. Bianchi, F. Dottori and L. Feyen. 2018. “Climatic and Socioeconomic Controls of Future Coastal Flood Risk in Europe.” *Nature Climate Change* 8 (9): 776–80. doi:10.1038/s41558-018-0260-4.

230. Pörtner, H.O., D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, K. Poloczanska, K. Mintenbeck et al., eds. 2019. *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*. https://report.ipcc.ch/srocc/pdf/SROCC_FinalDraft_FullReport.pdf.

231. Khanom, T. 2016. “Effect of Salinity on Food Security in the Context of Interior Coast of Bangladesh.” *Ocean & Coastal Management* 130 (October): 205–12. doi:10.1016/j.ocecoaman.2016.06.013.

232. Riahi, K., S. Rao, V. Krey, C. Cho, V. Chirkov, G. Fischer, G. Kindermann et al. 2011. “RCP 8.5: A Scenario of Comparatively High Greenhouse Gas Emissions.” *Climatic Change* 109 (1): 33. doi:10.1007/s10584-011-0149-y.

233. Hauer, M.E., E. Fussell, V. Mueller, M. Burkett, M. Call, K. Abel, R. McLeman and D. Wrathall. 2020. “Sea-Level Rise and Human Migration.” *Nature Reviews Earth & Environment* 1 (1): 28–39. doi:10.1038/s43017-019-0002-9.

234. Hauer, M.E., J.M. Evans and D.R. Mishra. 2016. “Millions Projected to Be at Risk from Sea-Level Rise in the Continental United States.” *Nature Climate Change* 6 (7): 691–95. doi:10.1038/nclimate2961.

235. OECD. 2018. *Making Development Co-operation Work for Small Island Developing States*. https://www.oecd-ilibrary.org/content/publication/9789264287648-en; Ourbak, T., and A.K. Magnan. 2018. "The Paris Agreement and Climate Change Negotiations: Small Islands, Big Players." *Regional Environmental Change* 18 (8): 2201–7. doi:10.1007/s10113-017-1247-9; Thomas, A., and L. Benjamin. 2018. "Policies and Mechanisms to Address Climate-Induced Migration and Displacement in Pacific and Caribbean Small Island Developing States." *International Journal of Climate Change Strategies and Management* 10 (1): 86–104. doi:10.1108/IJCCSM-03-2017-0055.

236. Allison et al. 2020. "The Human Relationship with Our Ocean Planet."

237. Bennett, N.J., A.M. Cisneros-Montemayor, J. Blythe, J.J. Silver, G. Singh, N. Andrews, A. Calò et al. 2019. "Towards a Sustainable and Equitable Blue Economy." *Nature Sustainability* 2 (11): 991–93. doi:10.1038/s41893-019-0404-1.

238. Österblom, H., C.C.C. Wabnitz and D. Tladi. 2020. "Towards Ocean Equity." Washington, DC: World Resources Institute. https://www.oceanpanel.org/sites/default/files/2020-04/towards-ocean-equity.pdf; Taylor, S.F.W., M.J. Roberts, B. Milligan and R. Ncwadi. 2019. "Measurement and Implications of Marine Food Security in the Western Indian Ocean: An Impending Crisis?" *Food Security* 11 (6): 1395–415. doi:10.1007/s12571-019-00971-6.

239. Tacon, A.G.J., and M. Metian. 2009. "Fishing for Feed or Fishing for Food: Increasing Global Competition for Small Pelagic Forage Fish." *Ambio* 38 (6): 294–302. doi:10.2307/40390239.

240. Garai, J. 2016. "Gender Specific Vulnerability in Climate Change and Possible Sustainable Livelihoods of Coastal People. A Case from Bangladesh." *Revista de Gestão Costeira Integrada* 16 (1): 79–88. doi:10.5894/rgci656; Akinsemolu, A.A., and O.A.P. Olukoya. 2020. "The Vulnerability of Women to Climate Change in Coastal Regions of Nigeria: A Case of the Ilaje Community in Ondo State." *Journal of Cleaner Production* 246 (February): 119015. doi:10.1016/j.jclepro.2019.119015.

241. Pörtner et al. 2019. "Summary for Policymakers." In *Special Report on the Ocean and Cryosphere in a Changing Climate*.

242. Holsman, K.K., E.L. Hazen, A. Haynie, S. Gourguet, A. Hollowed, S.J. Bograd, J.F. Samhouri and K. Aydin. 2019. "Towards Climate Resiliency in Fisheries Management." *ICES Journal of Marine Science* 76 (5): 1368–78. doi:10.1093/icesjms/fsz031.

243. Pörtner et al. 2019. "Summary for Policymakers." In *Special Report on the Ocean and Cryosphere in a Changing Climate*.

244. Charlton, K.E., J. Russell, E. Gorman, Q. Hanich, A. Delisle, B. Campbell and J. Bell. 2016. "Fish, Food Security and Health in Pacific Island Countries and Territories: A Systematic Literature Review." *BMC Public Health* 16 (1): 285. doi:10.1186/s12889-016-2953-9.

245. Harper, S., C. Grubb, M. Stiles and U.R. Sumaila. 2017. "Contributions by Women to Fisheries Economies: Insights from Five Maritime Countries." *Coastal Management* 45 (2): 91–106. doi:10.1080/08920753.2017.1278143.

246. Barange, M., T. Bahri, M.C.M. Beveridge, K.L. Cochrane, S. Funge-Smith and F. Poulain. 2018. "Impacts of Climate Change on Fisheries and Aquaculture: Synthesis of Current Knowledge, Adaptation and Mitigation Options." FAO Fisheries and Aquaculture Technical Paper no. 627. https://agris.fao.org/agris-search/search.do?recordID=XF2018002008.

247. Lopes, P.F.M., L. Mendes, V. Fonseca and S. Villasante. 2017. "Tourism as a Driver of Conflicts and Changes in Fisheries Value Chains in Marine Protected Areas." *Journal of Environmental Management* 200 (September): 123–34. doi:10.1016/j.jenvman.2017.05.080; Moreto, W.D., R.W. Charlton, S.E. DeWitt and C.M. Burton. 2019. "The Convergence of CAPTURED Fish and People: Examining the Symbiotic Nature of Labor Trafficking and Illegal, Unreported and Unregulated Fishing." *Deviant Behavior* 41 (6): 1–17. doi:10.1080/01639625.2019.1594587.

248. Allison et al. 2020. "The Human Relationship with Our Ocean Planet."

249. Witbooi, E., K.-D. Ali, M.A. Santosa, G. Hurley, Y. Husein, S. Maharaj, I. Okafor-Yarwood et al. 2020. "Organized Crime in the Fisheries Sector." Washington, DC: World Resources Institute. https://www.oceanpanel.org/blue-papers/organised-crime-associated-fisheries.

250. Widjaja, S., T. Long, H. Wirajuda, A. Gusman, S. Juwana, T. Ruchimat and C. Wilcox. 2020. "Illegal, Unreported and Unregulated Fishing and Associated Drivers." Washington, DC: World Resources Institute. https://oceanpanel.org/sites/default/files/2020-02/HLP%20Blue%20Paper%20on%20IUU%20Fishing%20and%20Associated%20Drivers.pdf; Witbooi et al. 2020. "Organized Crime in the Fisheries Sector."

251. Widjaja et al. 2020. "Illegal, Unreported and Unregulated Fishing and Associated Drivers"; Witbooi et al. 2020. "Organized Crime in the Fisheries Sector."

252. Lubchenco, J., and S.D. Gaines. 2019. "A New Narrative for the Ocean." *Science* 364 (6444): 911. doi:10.1126/science.aay2241.

253. Oceano Azul, Ocean Unite, Oak Foundation, David and Lucile Packard Foundation, Marine Conservation Institute, High Seas Alliance, Oceana et al. 2020. "RISE UP: A Blue Call to Action." https://www.riseupfortheocean.org/wp-content/uploads/2020/01/BCA_RISE-UP_EN_A4-1.pdf.

254. Allison et al. 2020. "The Human Relationship with Our Ocean Planet."

255. Bennett et al. 2019. "Towards a Sustainable and Equitable Blue Economy."

256. Kantar. 2020. "Perceptions of the Ocean and Environment."

257. Swilling, M., M. Ruckelshaus, T.B. Rudolph, P. Mbatha, E. Allison, S. Gelcich and H. Österblom. 2020. "The Ocean Transition: What to Learn from System Transitions." Washington, DC: World Resources Institute. https://www.oceanpanel.org/blue-papers/ocean-transition-what-learn-system-transitions.

258. Walter, J., R. Sharma and M. Ortiz. 2018. "Western Atlantic Bluefin Tuna Stock Assessment 1950–2015 Using Stock Synthesis." *ICCAT* 100; Commission for the Conservation of Southern Bluefin Tuna. n.d. "Latest Stock Assessment." https://www.ccsbt.org/en/content/latest-stock-assessment. Accessed 6 May 2020.

259. FAO. n.d. "The Status of the Fishing Fleet." http://www.fao.org/3/y5600e/y5600e05.htm. Accessed 6 May 2020.

260. Biancarosa, I., V. Sele, I. Belghit, R. Ørnsrud, E.-J. Lock and H. Amlund. 2019. "Replacing Fish Meal with Insect Meal in the Diet of Atlantic Salmon (*Salmo salar*) Does Not Impact the Amount of Contaminants in the Feed and It Lowers Accumulation of Arsenic in the Fillet." *Food Additives & Contaminants: Part A* 36 (8): 1191–205. doi:10.1080/19440049.2019.1619938.

261. Deady, S., S. Varian and J. Fives. 1995. "The Use of Cleaner-Fish to Control Sea Lice on Two Irish Salmon (*Salmo salar*) Farms with Particular Reference to Wrasse Behavior in Salmon Cages." *Aquaculture* 131 (March): 73–90. doi:10.1016/0044-8486(94)00331-H.

262. *The Explorer*. 2019. "Norwegian Technology for Sustainable Aquaculture." 14 August. https://www.theexplorer.no/stories/ocean/norwegian-technology-for-sustainable-aquaculture/.

263. Klinger, D., and R. Naylor. 2012. "Searching for Solutions in Aquaculture: Charting a Sustainable Course." *Annual Review of Environment and Resources* 37 (1): 247–76. doi:10.1146/annurev-environ-021111-161531.

264. Sandvik, A.D., I.A. Johnsen, M.S. Myksvoll, P.N. Sævik and M.D. Skogen. 2020. "Prediction of the Salmon Lice Infestation Pressure in a Norwegian Fjord." *ICES Journal of Marine Science* 77 (2): 746–56. doi:10.1093/icesjms/fsz256.

265. Buck, B.H., M.F. Troell, G. Krause, D.L. Angel, B. Grote and T. Chopin. 2018. "State of the Art and Challenges for Offshore Integrated Multi-trophic Aquaculture (IMTA)." *Frontiers in Marine Science* 5. doi:10.3389/fmars.2018.00165.

266. Hoegh-Guldberg et al. 2019. "The Ocean as a Solution to Climate Change."

267. Stehly, T.J., and P.C. Beiter. 2020. “2018 Cost of Wind Energy Review.” NREL/TP-5000-74598. Golden, CO: National Renewable Energy Lab. doi:10.2172/1581952.

268. IEA. 2019. *Offshore Wind Outlook 2019*.

269. Ørsted. n.d. “Making Green Energy Affordable: How the Offshore Wind Energy Industry Matured—and What We Can Learn from It.” https://orsted.com/-/media/WWW/Docs/Corp/COM/explore/Making-green-energy-affordable-June-2019.pdf.

270. Kempener, R., and F. Neumann. 2014. “Wave Energy Technology Brief.” International Renewable Energy Agency. https://www.irena.org/documentdownloads/publications/wave-energy_v4_web.pdf; Ocean Energy Systems (OES). 2015. “International LCOE for Ocean Energy Technologies: An Analysis of the Development Pathway and Levelised Cost of Energy Trajectories of Wave, Tidal and OTEC Technologies.” IEA Technology Collaboration Programme for Ocean Energy Systems. https://www.ocean-energy-systems.org/news/international-lcoe-for-ocean-energy-technology/.

271. IRENA. 2018. “Renewable Power Generation Costs in 2017.” Abu Dhabi: International Renewable Energy Agency. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Jan/IRENA_2017_Power_Costs_2018.pdf.

272. Draget, E. 2014. “Environmental Impacts of Offshore Wind Power Production in the North Sea.” Oslo: World Wide Fund for Nature. https://tethys.pnnl.gov/sites/default/files/publications/WWF-OSW-Environmental-Impacts.pdf.

273. Chestney, N. 2019. “IMO Agrees on Stricter Efficiency Targets for Some Ships.” Reuters, 17 May. https://uk.reuters.com/article/us-imo-shipping-efficiency-idUKKCN1SN2BV.

274. Olmer et al. 2017. “Greenhouse Gas Emissions from Global Shipping, 2013–2015.”

275. United Nations Conference on Trade and Development (UNCTAD). 2020. *Review of Maritime Transport 2019*. New York: UNCTAD. https://unctad.org/en/PublicationsLibrary/rmt2019_en.pdf.

276. Global Maritime Forum. n.d. “Getting to Zero Coalition.” https://www.globalmaritimeforum.org/getting-to-zero-coalition. Accessed 7 May 2020.

277. “Support for Green Maritime Methanol Project.” 2019. *Maritime Journal*, 21 February. https://www.maritimejournal.com/news101/power-and-propulsion/support-for-green-maritime-methanol-project.

278. Balsamo, F., C. Capasso, G. Miccione and O. Veneri. 2017. “Hybrid Storage System Control Strategy for All-Electric Powered Ships.” *Energy Procedia*, ATI 2017, 72nd Conference of the Italian Thermal Machines Engineering Association, September, 1083–90. doi:10.1016/j.egypro.2017.08.242; Filks, I. 2019. “Batteries Included: Sweden’s Emissions-Free Ferries Lead the Charge.” Reuters, 14 March. https://www.reuters.com/article/us-denmark-battery-ferry-idUSKCN1QV1W7.

279. Energy Transitions Commission (ETC). n.d. “Mission Possible: Reaching Net-Zero Carbon Emissions from Harder-to-Abate Sectors by Mid-century: Sectoral Focus Shipping.” http://www.energy-transitions.org/sites/default/files/ETC%20sectoral%20focus%20-%20Shipping_final.pdf. Accessed 7 May 2020.

280. IMO. n.d. “Ballast Water Management.” http://www.imo.org/en/OurWork/Environment/BallastWaterManagement/Pages/Default.aspx. Accessed 7 May 2020.

281. Global Environment Facility. 2017. “Global Treaty to Halt Invasive Aquatic Species Enters into Force.” 8 September. https://www.thegef.org/news/global-treaty-halt-invasive-aquatic-species-enters-force.

282. “Ballast Water Management Convention Amendments Enter Into Force.” 2019. *Maritime Executive*, 14 October. https://www.maritime-executive.com/article/ballast-water-management-convention-amendments-enter-into-force.

283. World Port Sustainability Program (WPSP). n.d. “About WPSP.” https://sustainableworldports.org/about/. Accessed 7 May 2020.

284. WPSP. 2019. “Port of Rotterdam: Incentive Scheme for Climate-Friendly Shipping.” https://sustainableworldports.org/project/port-of-rotterdam-incentive-scheme-for-climate-friendly-shipping/.

285. WPSP. 2019. “Port of Bari: Artificial Intelligence for Environmental Monitoring and Prediction.” https://sustainableworldports.org/project/port-of-bari-artificial-intelligence-for-environmental-monitoring-and-prediction/.

286. Turner, R.K., D. Burgess, D. Hadley, E. Coombes and N. Jackson. 2007. “A Cost-Benefit Appraisal of Coastal Managed Realignment Policy.” *Global Environmental Change* 17 (3): 397–407. doi:10.1016/j.gloenvcha.2007.05.006; Broekx, S., S. Smets, I. Liekens, D. Bulckaen and L. de Nocker. 2011. “Designing a Long-Term Flood Risk Management Plan for the Scheldt Estuary Using a Risk-Based Approach.” *Natural Hazards* 57 (2): 245–66. doi:10.1007/s11069-010-9610-x.

287. Temmerman, S., P. Meire, T.J. Bouma, P.M.J. Herman, T. Ysebaert and H.J. De Vriend. 2013. “Ecosystem-Based Coastal Defence in the Face of Global Change.” *Nature* 504 (7478): 79–83. doi:10.1038/nature12859.

288. Temmerman et al. 2013. “Ecosystem-Based Coastal Defence in the Face of Global Change.”

289. Temmerman et al. 2013. “Ecosystem-Based Coastal Defence in the Face of Global Change.”

290. Sala, E., and S. Giakoumi. 2018. “No-Take Marine Reserves Are the Most Effective Protected Areas in the Ocean.” *ICES Journal of Marine Science* 75 (3): 1166–68. doi:10.1093/icesjms/fsx059.

291. Babcock, R.C., N.T. Shears, A.C. Alcala, N.S. Barrett, G.J. Edgar, K.D. Lafferty, T.R. McClanahan and G.R. Russ. 2010. “Decadal Trends in Marine Reserves Reveal Differential Rates of Change in Direct and Indirect Effects.” *Proceedings of the National Academy of Sciences* 107 (43): 18256–61. doi:10.1073/pnas.0908012107.

292. Micheli, F., A. Saenz-Arroyo, A. Greenley, L. Vazquez, J.A. Espinoza Montes, M. Rossetto and G.A. de Leo. 2012. “Evidence That Marine Reserves Enhance Resilience to Climatic Impacts.” *PLOS ONE* 7 (7). doi:10.1371/journal.pone.0040832.

293. Roberts, C.M., B.C. O’Leary, D.J. McCauley, P.M. Cury, C.M. Duarte, J. Lubchenco, D. Pauly et al. 2017. ‘Marine Reserves Can Mitigate and Promote Adaptation to Climate Change’. *Proceedings of the National Academy of Sciences*, June. doi:"https://protect-eu.mimecast.com/s/EMSNCg2Vjh41YNUNcJ_J?domain=doi.org" 10.1073/pnas.1701262114.

294. Harrison, J. 2015. “Governing Marine Protected Areas: Resilience through Diversity, Written by Peter J.S. Jones.” *International Journal of Marine and Coastal Law* 30 (4): 811–13. doi:10.1163/15718085-12341373.

295. Convention on Biological Diversity. n.d. “Global Implementation.” https://www.cbd.int/protected/implementation/. Accessed 17 August 2020.

296. Marine Conservation Institute. n.d. “Interactive Map.” *Atlas of Marine Protection*. http://mpatlas.org./map/mpas/. Accessed 7 May 2020.

297. Costello, M.J., and B. Ballantine. 2015. “Biodiversity Conservation Should Focus on No-Take Marine Reserves: 94% of Marine Protected Areas Allow Fishing.” *Trends in Ecology & Evolution* 30 (9): 507–9. doi:10.1016/j.tree.2015.06.011.

298. Seltenrich, N. 2014. “Remote-Sensing Applications for Environmental Health Research.” *Environmental Health Perspectives* 122 (10): A268–75. doi:10.1289/ehp.122-A268.

299. Freeland, H.J., and P.F. Cummins. 2005. “Argo: A New Tool for Environmental Monitoring and Assessment of the World’s Oceans, an Example from the N.E. Pacific.” *Progress in Oceanography* 64 (1): 31–44. doi:10.1016/j.pocean.2004.11.002.

300. Stokey, R.P., A. Roup, C. von Alt, B. Allen, N. Forrester, T. Austin, R. Goldsborough et al. 2005. “Development of the REMUS 600 Autonomous Underwater Vehicle.” In *Proceedings of OCEANS 2005 MTS/IEEE* 2: 1301–4. doi:10.1109/OCEANS.2005.1639934.

301. Thomson, J., and J. Girton. 2017. "Sustained Measurements of Southern Ocean Air-Sea Coupling from a Wave Glider Autonomous Surface Vehicle." *Oceanography* 30 (2): 104–9.

302. Kelly, R.P. 2014. "Will More, Better, Cheaper, and Faster Monitoring Improve Environmental Management?" *Environmental Law* 44: 1111; Smith, L.M., J.A. Barth, D.S. Kelley, A. Plueddemann, I. Rodero, G.A. Ulses, M.F. Vardaro and R. Weller. 2018. "The Ocean Observatories Initiative." *Oceanography* 31 (1): 16–35.

303. Abbott, M.R., and C.E. Sears. 2006. "Always-Connected World and Its Impact on Ocean Research." *Advances in Computational Oceanography* 19 (1). 10.5670/oceanog.2006.88.

304. IllustrisTNG. 2019. "TNG." https://www.tng-project.org/about/.

305. Leape, J., M. Abbott, H. Sakaguchi et al. 2020. "Technology, Data and New Models for Sustainably Managing Ocean Resources." Washington, DC: World Resources Institute. https://www.oceanpanel.org/blue-papers/technology-data-and-new-models-sustainably-managing-ocean-resources.

306. Global Fishing Watch. n.d. "Sustainability through Transparency." https://globalfishingwatch.org/. Accessed 11 May 2020.

307. Peng, B., H. Hong, X. Xue and D. Jin. 2006. "On the Measurement of Socioeconomic Benefits of Integrated Coastal Management (ICM): Application to Xiamen, China." *Ocean & Coastal Management* 49 (3): 93–109. doi:10.1016/j.ocecoaman.2006.02.002.

308. Costello, C., D. Ovando, T. Clavelle, C.K. Strauss, R. Hilborn, M.C. Melnychuk, T.A. Branch et al. 2016. "Global Fishery Prospects under Contrasting Management Regimes." *Proceedings of the National Academy of Sciences* 113 (18): 5125–29. doi:10.1073/pnas.1520420113.

309. Reusch, T.B.H., J. Dierking, H.C. Andersson, E. Bonsdorff, J. Carstensen, M. Casini, M. Czajkowski et al. 2018. "The Baltic Sea as a Time Machine for the Future Coastal Ocean." *Science Advances* 4 (5): eaar8195. doi:10.1126/sciadv.aar8195.

310. Responsible Investor Research and Credit Suisse. 2020. *Investors and the Blue Economy*. https://www.esg-data.com/reports.

311. Brindley, G. 2019. *Financing and Investment Trends 2018: The European Wind Industry in 2018*. Wind Europe. https://windeurope.org/wp-content/uploads/files/about-wind/reports/Financing-and-Investment-Trends-2018.pdf.

312. Baltic and International Maritime Council (BIMCO), Cruise Lines International Association (CLIA), International Chamber of Shipping (ICS), INTERCARGO, INTERFERRY, International Association of Independent Tanker Owners (INTERTANKO), International Parcel Tankers Association (IPTA) and World-Class Shipping (WSC). 2019. "Reduction of GHG Emissions from Ships: Proposal to Establish an International Maritime Research and Development Board (IMRB)." Marine Environment Protection Committee, 75th Session, Agenda Item 7. https://www.ics-shipping.org/docs/default-source/Submissions/IMO/final-imrb-submission-to-mepc-75.pdf?sfvrsn=6.

313. Asian Development Bank. 2019. "ADB Launches $5 Billion Healthy Oceans Action Plan." 2 May. https://www.adb.org/news/adb-launches-5-billion-healthy-oceans-action-plan.

314. Ellen MacArthur Foundation. 2015. "Towards the Circular Economy, Economic and Business Rationale for an Accelerated Transition." https://www.ellenmacarthurfoundation.org/assets/downloads/TCE_Ellen-MacArthur-Foundation_9-Dec-2015.pdf.

315. Ellen MacArthur Foundation and Material Economics. 2019. "Completing the Picture: How the Circular Economy Tackles Climate Change." https://www.ellenmacarthurfoundation.org/assets/downloads/Completing_The_Picture_How_The_Circular_Economy-_Tackles_Climate_Change_V3_26_September.pdf; Ellen MacArthur Foundation. 2015. "Growth Within: A Circular Economy Vision for a Competitive Europe." Ellen MacArthur Foundation, Stiftungsfonds für Umweltökonomie und Nachhaltigkeit (SUN), and McKinsey Center for Business and the Environment. https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthurFoundation_Growth-Within_July15.pdf.

316. Lau et al. 2020. "Evaluating Scenarios toward Zero Plastic Pollution."

317. World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company. 2016. "The New Plastics Economy: Rethinking the Future of Plastics." http://www.ellenmacarthurfoundation.org/publications.

318. Agarwala, M.K. 2019. "Natural Capital Accounting and the Measurement of Sustainability." PhD diss., London School of Economics and Political Science. http://etheses.lse.ac.uk/4146/1/Agarwala__Natural-capital-accounting.pdf.

319. UN Statistical Division. 2019. "50th Session Documents." https://unstats.un.org/unsd/statcom/50th-session/documents/.

320. Adamowicz, W., L. Calderon-Etter, A. Entem, E.P. Fenichel, J.S. Hall, P. Lloyd-Smith, F.L. Ogden et al. 2019. "Assessing Ecological Infrastructure Investments." *Proceedings of the National Academy of Sciences* 116 (12): 5254–61. doi:10.1073/pnas.1802883116; Fenichel, E.P., and C. Obst. 2019. "A Framework for the Valuation of Ecosystem Assets." Discussion paer 5.3. In *System of Environmental Economic Accounting*, *2019 Forum of Experts in SEEA Experimental Ecosystem Accounting, 26–27 June 2019, Glen Cove, NY*. https://seea.un.org/sites/seea.un.org/files/discussion_paper_5.3.pdf.

321. Yun, S.D., E.P. Fenichel and J.K. Abbott. 2017. *Capital Asset Pricing for Nature*. Version 1.0.0. https://CRAN.R-project.org/package=capn.

322. Managi, S., and P. Kumar. 2018. *Inclusive Wealth Report 2018: Measuring Progress towards Sustainability*. New York: Routledge.

323. Natural Capital Coalition. n.d. "Natural Capital Protocol for the Ocean." https://naturalcapitalcoalition.org/wp-content/uploads/2019/01/Natural-Capital-Protocol-for-the-Ocean_Overview.pdf.

324. World Business Council for Sustainable Development. 2017. "What Experts Are Saying about the Natural Capital Protocol Toolkit." 13 July. https://www.wbcsd.org/Programs/Redefining-Value/Business-Decision-Making/Assess-and-Manage-Performance/Natural-Capital-Protocol-Toolkit/News/What-experts-are-saying-about-the-Natural-Capital-Protocol-Toolkit.

325. Ouyang, Z., C. Song, C. Wong, G.C. Daily, J. Liu, J. Salzman, L. Kong et al. 2019. "Designing Policies to Enhance Ecosystem Services: China's Experience on Mainstreaming Ecosystem Services for Green Growth." In *Green Growth That Works: Natural Capital Policy and Finance Mechanisms around the World*, edited by L. Mandle, Z. Ouyang, J. Salzman and G.C. Daily, 177–94. Washington, DC: Island.

326. Arkema, K.K., G.M. Verutes, S.A. Wood, C. Clarke-Samuels, S. Rosado, M. Canto, A. Rosenthal et al. 2015. "Embedding Ecosystem Services in Coastal Planning Leads to Better Outcomes for People and Nature." *Proceedings of the National Academy of Sciences* 112 (24): 7390–95. doi:10.1073/pnas.1406483112.

327. Leape et al. 2020. "Technology, Data and New Models for Sustainably Managing Ocean Resources."

328. NOAA. n.d. "ENOW Explorer: Discover More about Your Local Ocean Economy." https://coast.noaa.gov/enowexplorer/#/. Accessed 7 May 2020.

329. Many of the data needed to feed these dashboards and to parameterise these connections already exist, but they are highly dispersed. A first step towards understanding the dynamics at play is to highlight the current high-level status of ocean account data with a live version of the dashboard at https://environment.yale.edu/data-science/norwegian-ocean-economy-dashboard/.

330. Lubchenco and Gaines. 2019. "A New Narrative for the Ocean"; Lubchenco, J. 2019. "People and the Ocean 3.0: A New Narrative with Transformative Benefits." In *A Better Planet: 40 Big Ideas for a Sustainable Planet*. New Haven, CT: Yale University Press.

331. Lubchenco and Gaines. 2019. "A New Narrative for the Ocean"; Lubchenco. 2019. "People and the Ocean 3.0."

332. Lubchenco and Gaines. 2019. "A New Narrative for the Ocean"; Lubchenco. 2019. "People and the Ocean 3.0."

333. Bennett et al. 2019. "Towards a Sustainable and Equitable Blue Economy."

334. UN Environment Programme (UNEP). 2019. *The Emissions Gap Report 2019*. Nairobi: UNEP. https://www.unenvironment.org/resources/emissions-gap-report-2019.

335. Jessop, B. 2003. “The Governance of Complexity and the Complexity of Governance: Preliminary Remarks on Some Problems and Limits of Economic Guidance.” Department of Sociology at Lancaster University, 21. https://www.lancaster.ac.uk/fass/resources/sociology-online-papers/papers/jessop-governance-of-complexity.pdf.

336. Blockchain is a distributed ledger technology in which requests for transactions need to be validated by the entire network rather than by a single point. After validation, the transaction becomes an immutable block within the transaction’s history, which exists for as long as the network exists.

337. “MarinLit: A Database of the Natural Marine Product Literature.” 2020. Publishing Journals, Books and Databases. 7 May. http://pubs.rsc.org/marinlit/.

338. National Human Genome Research Institute. n.d. “DNA Sequencing Costs: Data.” https://www.genome.gov/about-genomics/fact-sheets/DNA-Sequencing-Costs-Data. Accessed 7 May 2020.

339. Haugan, P.M., L.A. Levin, D. Amon, M. Hemer, H. Lily and F.G. Nielsen. 2019. “What Role for Ocean-Based Renewable Energy and Deep-Seabed Minerals in a Sustainable Future?” Washington, DC: World Resources Institute. https://www.oceanpanel.org/blue-papers/ocean-energy-and-mineral-sources.

340. Dominish, E., S. Teske and N. Florin. 2019. *Responsible Minerals Sourcing for Renewable Energy*. Report prepared for Earthworks by the Institute for Sustainable Futures. Sydney: University of Technology Sydney. https://www.uts.edu.au/sites/default/files/2019-04/ISFEarthworks_Responsible%20minerals%20sourcing%20for%20renewable%20energy_Report.pdf.

341. van der Voet, E., L. van Oers, M. Verboon and K. Kuipers. 2019. “Environmental Implications of Future Demand Scenarios for Metals: Methodology and Application to the Case of Seven Major Metals.” *Journal of Industrial Ecology* 23 (1): 141–55. doi:10.1111/jiec.12722.

342. Gerard Barron (CEO and chairman of DeepGreen Metals). 2019. “Address to ISA Council.” presented at the Member of the Nauru Delegation, 27 February. https://ran-s3.s3.amazonaws.com/isa.org.jm/s3fs-public/files/documents/nauru-gb.pdf.

343. Jones, D.O.B., S. Kaiser, A.K. Sweetman, C.R. Smith, L. Menot, A. Vink, D. Trueblood et al. 2017. “Biological Responses to Disturbance from Simulated Deep-Sea Polymetallic Nodule Mining.” *PLOS ONE* 12 (2): e0171750. doi:10.1371/journal.pone.0171750.

344. Miller, K.A., K.F. Thompson, P. Johnston and D. Santillo. 2018. “An Overview of Seabed Mining Including the Current State of Development, Environmental Impacts, and Knowledge Gaps.” *Frontiers in Marine Science* 4. doi:10.3389/fmars.2017.00418; Sumaila, U.R., C.M. Rodriguez, M. Schultz, R. Sharma, T.D. Tyrrell, H. Masundire, A. Damodaran et al. 2017. “Investments to Reverse Biodiversity Loss Are Economically Beneficial.” *Current Opinion in Environmental Sustainability* 29 (December): 82–88. doi:10.1016/j.cosust.2018.01.007.

345. Tladi, D. 2014. “The Common Heritage of Mankind and the Proposed Treaty on Biodiversity in Areas beyond National Jurisdiction: The Choice between Pragmatism and Sustainability.” *Yearbook of International Environmental Law* 25 (1): 113–32. doi:10.1093/yiel/yvv060; Österblom et al. 2020. “Towards Ocean Equity.”

346. Miller et al. 2018. “An Overview of Seabed Mining Including the Current State of Development, Environmental Impacts, and Knowledge Gaps.”

347. Haugan et al. 2019. “What Role for Ocean-Based Renewable Energy and Deep-Seabed Minerals in a Sustainable Future?”

348. OECD. 2016. *The Ocean Economy in 2030*.

349. U.S. Energy Information Administration. 2016. “Offshore Oil Production in Deepwater and Ultra-deepwater Is Increasing.” *Today in Energy*, 28 October. https://www.eia.gov/todayinenergy/detail.php?id=28552.

350. Zhang, G., H. Qu, G. Chen, C. Zhao, F. Zhang, H. Yang, Z. Zhao and M. Ma. 2019. “Giant Discoveries of Oil and Gas Fields in Global Deepwaters in the Past 40 Years and the Prospect of Exploration.” *Journal of Natural Gas Geoscience* 4 (1): 1–28. doi:10.1016/j.jnggs.2019.03.002.

351. McGlade, C., and P. Ekins. 2015. “The Geographical Distribution of Fossil Fuels Unused When Limiting Global Warming to 2°C.” *Nature* 517 (7533): 187–90. doi:10.1038/nature14016.

352. IHS Markit. 2016. "Decommissioning of Aging Offshore Oil and Gas Facilities Increasing Significantly, with Annual Spending Rising to $13 Billion by 2040, IHS Markit Says". 29 November 2016. https://news.ihsmarkit.com/prviewer/release_only/slug/energy-power-media-decommissioning-aging-offshore-oil-and-gas-facilities-increasing-si; Elden, S. van, J.J. Meeuwig, R.J. Hobbs and J.M. Hemmi. 2019. "Offshore Oil and Gas Platforms as Novel Ecosystems: A Global Perspective". *Frontiers in Marine Science* 6. doi:10.3389/fmars.2019.00548.

353. Jepma, C.J., and M. van Schot. 2017. “On the Economics of Offshore Energy Conversion: Smart Combinations—Converting Offshore Wind Energy into Green Hydrogen on Existing Oil and Gas Platforms in the North Sea.” Energy Delta Institute. https://projecten.topsectorenergie.nl/storage/app/uploads/public/5d0/263/410/5d026341016a2991247120.pdf.

354. Jepma and van Schot. 2017. “On the Economics of Offshore Energy Conversion.”

355. FOA. 2020. “The Business Case for Marine Protection and Conservation”; Fowler, A.M., A.-M. Jørgensen, J.C. Svendsen, P.I. Macreadie, D.O. Jones, A.R. Boon, D.J. Booth et al. 2018. “Environmental Benefits of Leaving Offshore Infrastructure in the Ocean.” *Frontiers in Ecology and the Environment* 16 (10): 571–78. doi:10.1002/fee.1827; Jennifer Nalewicki. 2019. ‘The Gulf of Mexico’s Hottest Diving Spots Are Decommissioned Oil Rigs’. *Smithsonian Magazine*, 5 April 2019, sec. Travel. https://www.smithsonianmag.com/travel/gulf-mexicos-hottest-diving-spots-are-decommissioned-oil-rigs-180971728/.

356. Gaines et al. 2019. “The Expected Impacts of Climate Change on the Ocean Economy.”

357. Hoegh-Guldberg et al. 2019. “The Ocean as a Solution to Climate Change.”

358. Lau et al. 2020. “Evaluating Scenarios toward Zero Plastic Pollution”; Pew Charitable Trusts and SYSTEMIQ. 2020. *Breaking the Plastic Wave*.

359. Lau et al. 2020. “Evaluating Scenarios toward Zero Plastic Pollution”; Pew Charitable Trusts and SYSTEMIQ. 2020. *Breaking the Plastic Wave*.

360. ETC. n.d. “Mission Possible.”

361. Ferrario, F., M.W. Beck, C.D. Storlazzi, F. Micheli, C.C. Shepard and L. Airoldi. 2014. “The Effectiveness of Coral Reefs for Coastal Hazard Risk Reduction and Adaptation.” *Nature Communications* 5 (1): 3794. doi:10.1038/ncomms4794.

362. Mapping Ocean Wealth (The Nature Conservancy). n.d. “Coastal Protection.” https://oceanwealth.org/ecosystem-services/coastal-protection/. Accessed 11 May 2020.

363. Mapping Ocean Wealth (The Nature Conservancy). n.d. “Coastal Protection.”

364. McCann, K.S. 2000. “The Diversity–Stability Debate.” *Nature* 405 (6783): 228–33. doi:10.1038/35012234.

365. Oregon State University, IUCN World Commission on Protected Areas, Marine Conservation Institute, National Geographic Society and UNEP World Conservation Monitoring Centre. 2019. “An Introduction to the MPA Guide.” https://www.protectedplanet.net/c/mpa-guide.

366. Dinerstein, E., C. Vynne, E. Sala, A.R. Joshi, S. Fernando, T.E. Lovejoy, J. Mayorga et al. 2019. “A Global Deal for Nature: Guiding Principles, Milestones, and Targets.” *Science Advances* 5 (4): eaaw2869. doi:10.1126/sciadv.aaw2869.

367. Bosch, J., I. Staffell and A.D. Hawkes. 2018. “Temporally Explicit and Spatially Resolved Global Offshore Wind Energy Potentials.” *Energy* 163 (November): 766–81. doi:10.1016/j.energy.2018.08.153.

368. IEA. n.d. “Data & Statistics”; Haugan et al. 2019. “What Role for Ocean-Based Renewable Energy and Deep-Seabed Minerals in a Sustainable Future?”

369. Bosch et al. 2018. “Temporally Explicit and Spatially Resolved Global Offshore Wind Energy Potentials”; IEA. n.d. “Data & Statistics.”

370. Including tidal stream and tidal range energies. Retrieved from Haugan et al. 2019. “What Role for Ocean-Based Renewable Energy and Deep-Seabed Minerals in a Sustainable Future?”

371. Haugan et al. 2019. “What Role for Ocean-Based Renewable Energy and Deep-Seabed Minerals in a Sustainable Future?”

372. Haugan et al. 2019. “What Role for Ocean-Based Renewable Energy and Deep-Seabed Minerals in a Sustainable Future?”

373. Haugan et al. 2019. “What Role for Ocean-Based Renewable Energy and Deep-Seabed Minerals in a Sustainable Future?”

374. IEA. 2019. “World Energy Outlook 2019—Analysis.” https://www.iea.org/reports/world-energy-outlook-2019.

375. OECD. 2016. *The Ocean Economy in 2030*.

376. IRENA. 2019. “Future of Wind.”

377. Hoegh-Guldberg et al. 2019. “The Ocean as a Solution to Climate Change.”

378. Costello et al. 2019. “The Future of Food from the Sea.”

379. Costello et al. 2019. “The Future of Food from the Sea.”

380. MSY and MEY: Maximum sustainable yield (MSY) is the long-term maximum amount of catch for a given fishery, purely based on the stock’s biology. Maximum economic yield (MEY) adds the dimension of fishing costs to optimize for the most profitable, sustainable amount of catch, which is generally slightly lower than MSY catch. Information retrieved from World Ocean Review. “The Profits of Fishing.” Maribus, after Quaas. n.d. “The Profits of Fishing: World Ocean Review.” https://worldoceanreview.com/en/wor-1/fisheries/causes-of-overfishing/the-profits-of-fishing/. Accessed 18 August 2020.

381. Costello et al. 2019. “The Future of Food from the Sea.”

382. Costello et al. 2019. “The Future of Food from the Sea.”

383. Costello et al. 2019. “The Future of Food from the Sea.”

384. Costello et al. 2019. “The Future of Food from the Sea.”

385. Costello et al. 2019. “The Future of Food from the Sea.”

386. Costello et al. 2019. “The Future of Food from the Sea.”

387. UNCTAD. 2020. “The COVID-19 Pandemic and the Blue Economy: New Challenges and Prospects for Recovery and Resilience.” https://unctad.org/en/PublicationsLibrary/ditctedinf2020d2_en.pdf.

388. Northrop, E., M. Konar, N. Frost and E. Hollaway. 2020. “A Sustainable and Equitable Blue Recovery to the COVID-19 Crisis.” Washington, DC: World Resources Institute.

389. OECD. 2016. *The Ocean Economy in 2030*.

390. Gilman, P., B. Maurer, L. Feinberg, A. Duerr, L. Peterson, W. Musial, P. Beiter et al. 2016. “National Offshore Wind Strategy: Facilitating the Development of the Offshore Wind Industry in the United States.” DOE/GO-102016-4866. EERE Publication and Product Library. doi:10.2172/1325403.

391. OECD. 2016. *The Ocean Economy in 2030*.

392. QinetiQ, Lloyd’s Register and University of Strathclyde Glasgow. 2013. “Global Marine Trends 2030.” http://www.futurenautics.com/wp-content/uploads/2013/10/GlobalMarineTrends2030Report.pdf.

393. Chuenpagdee, R., L. Liguori, M.L.D. Palomares and D. Pauly. 2006. “Bottom-up, Global Estimates of Small-Scale Marine Fisheries Catches.” doi:10.14288/1.0074761.

394. FAO Fisheries and Aquaculture Department. n.d. “Small-Scale Fisheries around the World.”

395. OECD. 2016. *The Ocean Economy in 2030*.

396. OECD. 2016. *The Ocean Economy in 2030*.

397. “Sea Intelligence: COVID-19 Impact Pushes Carriers’ Revenue Loss to USD 1.9 Bln.” 2020. Offshore Energy (blog), 3 March. https://www.offshore-energy.biz/sea-intelligence-covid-19-impact-pushes-carriers-revenue-loss-to-usd-1-9-bln/.

398. Konar and Ding. 2020. “A Sustainable Ocean Economy for 2050.”

399. Konar and Ding. 2020. “A Sustainable Ocean Economy for 2050.”

400. Lau et al. 2020. “Evaluating Scenarios toward Zero Plastic Pollution”; Pew Charitable Trusts and SYSTEMIQ. 2020. *Breaking the Plastic Wave*.

401. Food and Land Use Coalition (FOLU). 2019. *Growing Better: Ten Critical Transitions to Transform Food and Land Use*. https://www.foodandlandusecoalition.org/wp-content/uploads/2019/09/FOLU-GrowingBetter-GlobalReport.pdf.

402. Bennett et al. 2019. “Towards a Sustainable and Equitable Blue Economy.”

403. Österblom et al. 2020. “Towards Ocean Equity.”

404. UNDP. 2018. “What Does It Mean to Leave No One Behind?” UN Development Programme. http://www.undp.org/content/dam/undp/library/Sustainable%20Development/2030%20Agenda/Discussion_Paper_LNOB_EN_lres.pdf.

405. OECD. 2020. *Sustainable Ocean for All*. https://www.oecd-ilibrary.org/docserver/bede6513-en.pdf?expires=1600102426&id=id&accname=guest&checksum=3BDD63D736252E0053B068682425AFEB.

406. Definition of procedural equity by Österblom et al. 2020. “Towards Ocean Equity.” Procedural equity refers to the recognition of rights and needs of all groups and the level of inclusion and participation in decision-making related to ocean development.

407. IMO. n.d. “Women in Maritime: IMO’s Gender Programme.” http://www.imo.org/en/OurWork/TechnicalCooperation/Pages/WomenInMaritime.aspx. Accessed 11 May 2020.

408. Österblom et al. 2020. “Towards Ocean Equity.”

409. Inniss et al. 2016. “The First Global Integrated Marine Assessment.”

410. Österblom et al. 2020. “Towards Ocean Equity.”

411. Österblom et al. 2020. “Towards Ocean Equity.”

412. Swilling et al. 2020. “The Ocean Transition.”

413. Fanzo, J., C. Hawkes, E. Udomkesmalee, A. Afshin, L. Allemandi, O. Assery, P. Baker et al. 2018. “2018 Global Nutrition Report: Shining a Light to Spur Action on Nutrition.” Monograph. Bristol, UK: Development Initiatives. https://globalnutritionreport.org/reports/global-nutrition-report-2018/.

414. James, D. 2013. “Risks and Benefits of Seafood Consumption.” Rome: Food and Agriculture Organization of the United Nations, GLOBEFISH. http://www.fao.org/3/a-bb211e.pdf.

415. Willett et al. 2019. “Food in the Anthropocene.”

416. Tacon, A.G.J., and M. Metian. 2013. “Fish Matters: Importance of Aquatic Foods in Human Nutrition and Global Food Supply.” *Reviews in Fisheries Science* 21 (1): 22–38. doi:10.1080/10641262.2012.753405.

417. Díaz et al. 2019. “Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.”

418. Wang, F., H.M. Orpana, H. Morrison, M. de Groh, S. Dai and W. Luo. 2012. “Long-Term Association between Leisure-Time Physical Activity and Changes in Happiness: Analysis of the Prospective National Population Health Survey.” *American Journal of Epidemiology* 176 (12): 1095–1100. doi:10.1093/aje/kws199.

419. Cisneros-Montemayor, A.M., and U.R. Sumaila. 2010. "A Global Estimate of Benefits from Ecosystem-Based Marine Recreation: Potential Impacts and Implications for Management." *Journal of Bioeconomics* 12 (3): 245–68. doi:10.1007/s10818-010-9092-7.

420. Inniss et al. 2016. "The First Global Integrated Marine Assessment."

421. Singh, G.G., A.M. Cisneros-Montemayor, W. Swartz, W. Cheung, J.A. Guy, T.-A. Kenny, C.J. McOwen et al. 2018. "A Rapid Assessment of Co-benefits and Trade-offs among Sustainable Development Goals." *Marine Policy* 93 (July): 223–31. doi:10.1016/j.marpol.2017.05.030.

422. Costello et al. 2019. "The Future of Food from the Sea."

423. IEA. n.d. "Data & Statistics."

424. Singh et al. 2018. "A Rapid Assessment of Co-benefits and Trade-offs among Sustainable Development Goals."

425. UNEP. 2019. *The Emissions Gap Report 2019*.

426. Levin, S.A., and J. Lubchenco. 2008. "Resilience, Robustness, and Marine Ecosystem-Based Management." *BioScience* 58 (1): 27–32. doi:10.1641/B580107.

427. Lubchenco et al. 2016. "The Right Incentives Enable Ocean Sustainability Successes and Provide Hope for the Future."

428. Lubchenco et al. 2016. "The Right Incentives Enable Ocean Sustainability Successes and Provide Hope for the Future."

429. UNESCO. n.d. "Ocean Governance and Institutional Challenges." http://www.unesco.org/new/en/natural-sciences/ioc-oceans/focus-areas/rio-20-ocean/ocean-governance/.

430. UNESCO. n.d. "Ocean Governance and Institutional Challenges."

431. Ostrom, E. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge: Cambridge University Press.

432. Independent Group of Scientists appointed by the Secretary-General. 2019. *Global Sustainable Development Report 2019: The Future Is Now—Science for Achieving Sustainable Development*. New York: United Nations. https://sustainabledevelopment.un.org/content/documents/24797GSDR_report_2019.pdf.

433. Pew Charitable Trusts. 2019. "International Fisheries Managers' Response to Performance Reviews Insufficient." https://www.pewtrusts.org/-/media/assets/2019/04/international_fisheries_managers_underuse_performance_review_guidance_v1.pdf.

434. Hutniczak, B., C. Delpeuch and A. Leroy. 2019. "Intensifying the Fight against IUU Fishing at the Regional Level." OECD Food, Agriculture and Fisheries Papers, no. 121 (February). doi:https://doi.org/10.1787/b7b9f17d-en.

435. Bell, J.B., E. Guijarro-Garcia and A. Kenny. 2019. "Demersal Fishing in Areas beyond National Jurisdiction: A Comparative Analysis of Regional Fisheries Management Organisations." *Frontiers in Marine Science* 6. doi:10.3389/fmars.2019.00596; Brooks, C.M., L.B. Crowder, L.M. Curran, R.B. Dunbar, D.G. Ainley, K.J. Dodds, K.M. Gjerde and U.R. Sumaila. 2016. "Science-Based Management in Decline in the Southern Ocean." *Science* 354 (6309): 185–87. doi:10.1126/science.aah4119.

436. Frazão Santos, C., C.N. Ehler, T. Agardy, F. Andrade, M.K. Orbach and L.B. Crowder. 2019. "Marine Spatial Planning." Chapter 30 in *World Seas: An Environmental Evaluation*, 2nd ed., edited by C. Sheppard, 571–92. Cambridge, MA: Academic Press. doi:10.1016/B978-0-12-805052-1.00033-4.

437. Porter, G. 1998. *Estimating Overcapacity in the Global Fishing Fleet*. Washington, DC: World Wildlife Fund.

438. Sumaila, U.R., W. Cheung, A. Dyck, K. Gueye, L. Huang, V. Lam, D. Pauly et al. 2012. "Benefits of Rebuilding Global Marine Fisheries Outweigh Costs." *PLOS ONE* 7 (7). doi:10.1371/journal.pone.0040542.

439. Sumaila et al. 2012. "Benefits of Rebuilding Global Marine Fisheries Outweigh Costs."

440. Teh, L., W.W.L. Cheung, A. Cornish, C. Chu and U.R. Sumaila. 2008. "A Survey of Alternative Livelihood Options for Hong Kong's Fishers." *International Journal of Social Economics* 35 (5): 380–95. doi:10.1108/03068290810861620.

441. Sumaila et al. 2012. "Benefits of Rebuilding Global Marine Fisheries Outweigh Costs."

442. IEA. 2019. *Offshore Wind Outlook 2019*.

443. Lubchenco et al. 2016. "The Right Incentives Enable Ocean Sustainability Successes and Provide Hope for the Future."

444. Millennium Ecosystem Assessment (Program), ed. 2005. *Ecosystems and Human Well-Being*.

445. OECD Data. n.d. "Agricultural Output: Meat Consumption." http://data.oecd.org/agroutput/meat-consumption.htm. Accessed 11 May 2020.

446. Swilling et al. 2020. "The Ocean Transition."

447. Sunderji, N. 2016. "How Will Data and Digital Platforms Transform Sustainable Development?" *Devex*, 25 July. https://www.devex.com/news/sponsored/how-will-data-and-digital-platforms-transform-sustainable-development-88481.

448. Bollier, D. 2016. "Transnational Republics of Commoning 2: New Forms of Network-Based Governance." *P2P Foundation* (blog), 16 September. https://blog.p2pfoundation.net/transnational-republics-of-commoning-2-new-forms-of-network-based-governance/2016/09/16.

449. Bollier, D. 2016. "Transnational Republics of Commoning 2."

450. Bollier, D. 2016. "Transnational Republics of Commoning 2."

451. Swilling et al. 2020. "The Ocean Transition."

452. Bennett, N.J., T.S. Whitty, E. Finkbeiner, J. Pittman, H. Bassett, S. Gelcich and E.H. Allison. 2018. "Environmental Stewardship: A Conceptual Review and Analytical Framework." *Environmental Management* 61 (4): 597–614. doi:10.1007/s00267-017-0993-2.

453. Costello et al. 2016. "Global Fishery Prospects under Contrasting Management Regimes."

454. Blasiak, R., R. Wynberg, K. Grorud-Colvert, S. Thambisetty et al. 2020. "The Ocean Genome: Conservation and the Fair, Equitable and Sustainable Use of Marine Genetic Resources." Washington, DC: World Resources Institute. www.oceanpanel.org/blue-papers/ocean-genome-conservation-andfair-equitable-and-sustainable-use-marine-genetic.

455. Pauly et al. n.d. "Sea around Us Concepts, Design and Data."

456. Global Fishing Watch. n.d. "Sustainability through Transparency."

457. Nyborg, K., J.M. Anderies, A. Dannenberg, T. Lindahl, C. Schill, M. Schlüter, W.N. Adger et al. 2016. "Social Norms as Solutions." *Science* 354 (6308): 42–43. doi:10.1126/science.aaf8317; Leape et al. 2020. "Technology, Data and New Models for Sustainably Managing Ocean Resources."

458. Hardt, M.J., K. Flett and C.J. Howell. 2017. "Current Barriers to Large-Scale Interoperability of Traceability Technology in the Seafood Sector." *Journal of Food Science* 82 (S1): A3–12. doi:10.1111/1750-3841.13796.

459. Bailey, R.M., E. Carrella, R. Axtell, M.G. Burgess, R.B. Cabral, M. Drexler, C. Dorsett et al. 2019. "A Computational Approach to Managing Coupled Human-Environmental Systems: The POSEIDON Model of Ocean Fisheries." *Sustainability Science* 14 (2): 259–75. doi:10.1007/s11625-018-0579-9.

460. Maxwell, S.M., E.L. Hazen, R.L. Lewison, D.C. Dunn, H. Bailey, S.J. Bograd, D.K. Briscoe et al. 2015. "Dynamic Ocean Management: Defining and Conceptualizing Real-Time Management of the Ocean." *Marine Policy* 58 (August): 42–50. doi:10.1016/j.marpol.2015.03.014.

461. Dunn, D.C., A.M. Boustany and P.N. Halpin. 2011. "Spatio-temporal Management of Fisheries to Reduce By-Catch and Increase Fishing Selectivity." *Fish and Fisheries* 12 (1): 110–19. doi:10.1111/j.1467-2979.2010.00388.x.

462. OECD. 2019. *Rethinking Innovation for a Sustainable Ocean Economy*. Paris: Organisation for Economic Co-operation and Development. doi:10.1787/9789264311053-en.

463. Intergovernmental Oceanographic Commission (IOC)-UNESCO. 2017. *Global Ocean Science Report: The Current Status of Ocean Science around the World*. Edited by L. Valdés et al. Paris: UNESCO Publishing. https://unesdoc.unesco.org/ark:/48223/pf0000250428.

464. IOC-UNESCO. 2017. *Global Ocean Science Report*.

465. McConney, P., L. Fanning, R. Mahon and B. Simmons. 2016. “A First Look at the Science-Policy Interface for Ocean Governance in the Wider Caribbean Region.” *Frontiers in Marine Science* 2. doi:10.3389/fmars.2015.00119.

466. Stelzenmüller, V., J. Lee, A. South, J. Foden and S.I. Rogers. 2013. “Practical Tools to Support Marine Spatial Planning: A Review and Some Prototype Tools.” *Marine Policy* 38 (March): 214–27. doi:10.1016/j.marpol.2012.05.038.

467. Campbell, J., and D. Jensen. 2019. “Building a Digital Ecosystem for the Planet.” Foresight Brief no. 014 (September). UN Environment Programme. https://wedocs.unep.org/handle/20.500.11822/30612.

468. Buck, J.J.H., S.J. Bainbridge, E.F. Burger, J. del Río Fernandez, E. Delory, P. Fischer, S. Jirka and J.S. Pearlman. 2019. “Ocean Data Product Integration through Innovation: The Next Level of Data Interoperability.” *Frontiers in Marine Science* 6 (February): 32/1–32/19. doi:10.3389/fmars.2019.00032.

469. Leape et al. 2020. “Technology, Data and New Models for Sustainably Managing Ocean Resources.”

470. Leape et al. 2020. “Technology, Data and New Models for Sustainably Managing Ocean Resources.”

471. Leape et al. 2020. “Technology, Data and New Models for Sustainably Managing Ocean Resources.”

472. Leape et al. 2020. “Technology, Data and New Models for Sustainably Managing Ocean Resources.”

473. Cater, N.E., P. Eng and T. O’Reilly. 2009. “Promoting Interoperable Ocean Sensors the Smart Ocean Sensors Consortium.” In *OCEANS 2009*, 1–6. doi:10.23919/OCEANS.2009.5422448.

474. Leape et al. 2020. “Technology, Data and New Models for Sustainably Managing Ocean Resources.”

475. Harden-Davies, H. 2017. “Capacity Building and Technology Transfer for Marine Biodiversity in Areas beyond National Jurisdiction.” *Proceedings of the ASIL Annual Meeting* 111: 243–45. doi:10.1017/amp.2017.75.

476. Costello, C., S.D. Gaines and J. Lynham. 2008. “Can Catch Shares Prevent Fisheries Collapse?” *Science* 321 (5896): 1678–81. doi:10.1126/science.1159478.

477. Marine Spatial Planning Programme, UNESCO and IOC. n.d. “Balancing Sustainable Use and Conservation through Marine Spatial Planning.” http://msp.ioc-unesco.org/. Accessed 12 May 2020.

478. Smith, S. 2017. “Just Transition: A Report for the OECD.” Just Transition Centre. https://search.oecd.org/environment/cc/g20-climate/collapsecontents/Just-Transition-Centre-report-just-transition.pdf.

479. Canada’s Task Force on Just Transition for Canadian Coal Power Workers and Communities. 2018. *Final Report by the Task Force on Just Transition for Canadian Coal Power Workers and Communities*. Government of Canada. https://www.canada.ca/en/environment-climate-change/services/climate-change/task-force-just-transition/final-report-complete.html.

480. Environmental Defense Fund. n.d. “Database.” Fishery Solutions Center. http://fisherysolutionscenter.edf.org/database. Accessed 12 May 2020.

481. IOC-UNESCO. 2017. *Global Ocean Science Report*.

482. Weeks, R., R.L. Pressey, J.R. Wilson, M. Knight, V. Horigue, R.A. Abesamis, R. Acosta and J. Jompa. 2015. “Ten Things to Get Right for Marine Conservation Planning in the Coral Triangle.” *F1000Research* 3 (December). doi:10.12688/f1000research.3886.3.

483. Weeks et al. 2015. “Ten Things to Get Right for Marine Conservation Planning in the Coral Triangle”; Frazão Santos, C., T. Agardy, F. Andrade, H. Calado, L.B. Crowder, C.N. Ehler, S. García-Morales, et al. 2020. ‘Integrating Climate Change in Ocean Planning’. Nature Sustainability 3 (7): 505–16. doi:10.1038/s41893-020-0513-x.

484. Allison et al. 2020. “The Human Relationship with Our Ocean Planet.”

485. Libes, L., and M. Eldridge. 2019. “Who, What, Where and How: 440 Investors—a Deepening View of Impact Investing.” http://investorflow.org/wp-content/uploads/Investorflow-Report-440-Investors-March-2019.pdf.

486. OECD. 2020. *Sustainable Ocean for All*.

487. UNCTAD. 2014. *World Investment Report 2014: Investing in the SDGs—an Action Plan*. United Nations Conference on Trade and Development World Investment Report. New York: United Nations. doi:10.18356/3e74cde5-en. Sumaila et al. 2017. “Investments to Reverse Biodiversity Loss Are Economically Beneficial.”

488. Sumaila, U.R., C.M. Rodriguez, M. Schultz, R. Sharma, T.D. Tyrrell, H. Masundire, A. Damodaran et al. 2017. “Investments to Reverse Biodiversity Loss Are Economically Beneficial.” *Current Opinion in Environmental Sustainability* 29 (December): 82–88. doi:10.1016/j.cosust.2018.01.007.

489. Sumaila et al. 2012. “Benefits of Rebuilding Global Marine Fisheries Outweigh Costs.”

490. Responsible Investor Research and Credit Suisse. 2020. *Investors and the Blue Economy*.

491. Schuhbauer, A., R. Chuenpagdee, W.W.L. Cheung, K. Greer and U.R. Sumaila. 2017. “How Subsidies Affect the Economic Viability of Small-Scale Fisheries.” *Marine Policy* 82 (August): 114–21. doi:10.1016/j.marpol.2017.05.013.

492. Karousakis, K. 2018. “Evaluating the Effectiveness of Policy Instruments for Biodiversity: Impact Evaluation, Cost-Effectiveness Analysis and Other Approaches.” OECD Environment Working Paper no. 141. Organisation for Economic Co-operation and Development.

493. Sumaila et al. 2012. “Benefits of Rebuilding Global Marine Fisheries Outweigh Costs.”

494. Sumaila et al. 2012. “Benefits of Rebuilding Global Marine Fisheries Outweigh Costs.”

495. Sumaila et al. 2012. “Benefits of Rebuilding Global Marine Fisheries Outweigh Costs.”

496. Fitzgerald, T.P., P.R. Higgins, E. Quilligan, S.A. Sethi and J.T. la Puente. 2020. “Catalysing Fisheries Conservation Investment.” *Frontiers in Ecology and the Environment* 18 (3): 151–58. doi:10.1002/fee.2147.

497. Ocean Fox Advisory and Friends of Ocean Action (FOA). n.d. *The Ocean Finance Handbook: Increasing Finance for a Healthy Ocean*. http://www3.weforum.org/docs/WEF_FOA_The_Ocean_Finance_Handbook_April_2020.pdf.

498. Wylie et al. 2016. “Keys to Successful Blue Carbon Projects.”

499. Blended Finance Taskforce (BFT). 2018. “Better Finance Better World.” London: BFT, Business and Sustainable Development Commission, SYSTEMIQ. https://www.blendedfinance.earth/better-finance-better-world.

500. Ocean Fox Advisory and Friends of the Ocean Action. n.d. *The Ocean Finance Handbook*.

501. OECD. 2018. *OECD Companion to the Inventory of Support Measures for Fossil Fuels 2018*. Paris: OECD Publishing. https://www.oecd-ilibrary.org/content/publication/9789264286061-en.

502. Lau et al. 2020. “Evaluating Scenarios toward Zero Plastic Pollution”; Pew Charitable Trusts and SYSTEMIQ. 2020. *Breaking the Plastic Wave*.

503. World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company. 2016. “The New Plastics Economy: Rethinking the Future of Plastics.”

504. Laffoley and Baxter. 2019. *Ocean Deoxygenation*.

505. Laffoley and Baxter. 2019. *Ocean Deoxygenation*.

506. U.S. Food and Drug Administration. 2019. "Advice about Eating Fish: For Women Who Are or Might Become Pregnant, Breastfeeding Mothers, and Young Children." 7 February. https://www.fda.gov/food/consumers/advice-about-eating-fish; National Health Service. 2018. "Should Pregnant and Breastfeeding Women Avoid Some Types of Fish?" 4 July. https://www.nhs.uk/common-health-questions/pregnancy/should-pregnant-and-breastfeeding-women-avoid-some-types-of-fish/.

507. McClain, C.R., C. Nunnally and M.C. Benfield. n.d. "Persistent and Substantial Impacts of the Deepwater Horizon Oil Spill on Deep-Sea Megafauna." *Royal Society Open Science* 6 (8): 191164. doi:10.1098/rsos.191164; NOAA Office of Response and Restoration. n.d. "At the Bottom of the Gulf of Mexico, Corals and Diversity Suffered after Deepwater Horizon Oil Spill." https://response.restoration.noaa.gov/about/media/bottom-gulf-mexico-corals-and-diversity-suffered-after-deepwater-horizon-oil-spill.html. Accessed 12 May 2020.

508. Lau et al. 2020. "Evaluating Scenarios toward Zero Plastic Pollution"; Pew Charitable Trusts and SYSTEMIQ. 2020. *Breaking the Plastic Wave*.

509. Lau et al. 2020. "Evaluating Scenarios toward Zero Plastic Pollution"; Pew Charitable Trusts and SYSTEMIQ. 2020. *Breaking the Plastic Wave*.

510. FOLU. 2019. *Growing Better*.

511. See Blue Paper 8 for a more in-depth review: Fenichel, E.P., B. Milligan, I. Porras et al. 2020. "National Accounting for the Ocean and Ocean Economy." Washington, DC: World Resources Institute. https://www.oceanpanel.org/blue-papers/national-accounting-ocean-and-ocean-economy.

512. High Level Expert Group on the Measurement of Economic Performance and Social Progress. n.d. "Measurement of Economic Performance and Social Progress." https://www.oecd.org/statistics/measuring-economic-social-progress/. Accessed 12 May 2020.

513. Landefeld, J.S. 2000. "GDP: One of the Great Inventions of the 20th Century." *Survey of Current Business* 80 (1) (January): 4.

514. Bateman, I., A. Binner, B. Day, C. Fezzi, A. Rusby, G. Smith and R. Welters. 2019. "United Kingdom: Paying for Ecosystem Services in the Public and Private Sectors." In *Green Growth That Works: Natural Capital Policy and Finance Mechanisms from around the World*, edited by L. Mandle, Z. Ouyang, J.E. Salzman and G. Daily, 237–54. Washington, DC: Island Press/Center for Resource Economics. doi:10.5822/978-1-64283-004-0_15.

515. Quesada, A.U. 2019. "Costa Rica: Bringing Natural Capital Values into the Mainstream." In *Green Growth That Works: Natural Capital Policy and Finance Mechanisms from around the World*, edited by L. Mandle, Z. Ouyang, J.E. Salzman and G. Daily, 195–212. Washington, DC: Island Press/Center for Resource Economics. doi:10.5822/978-1-64283-004-0_13.

516. Ouyang, Z., C. Song, H. Zheng, S. Polasky, Y. Xiao, I. Bateman, J. Liu et al. 2020. "Using Gross Ecosystem Product (GEP) to Value Nature in Decision-Making." https://ore.exeter.ac.uk/repository/handle/10871/120272.

517. UN Economic and Social Council. n.d. *2013/21. Fundamental Principles of Official Statistics*. https://unstats.un.org/unsd/dnss/gp/FP-Rev2013-E.pdf.

518. UN Department of Economic and Social Affairs, Statistical Division. n.d. "System of National Accounts." https://unstats.un.org/unsd/nationalaccount/sna.asp. Accessed 12 May 2020; United Nations. n.d. "System of Environmental Economic Accounting." https://seea.un.org/. Accessed 12 May 2020.

519. FAO, ed. 2018. *The State of World Fisheries and Aquaculture 2018*.

520. FAO, ed. 2018. *The State of World Fisheries and Aquaculture 2018*.

521. Lund, E.K. 2013. "Health Benefits of Seafood: Is It Just the Fatty Acids?" *Food Chemistry*, Ninth International Food Data Conference: Food Composition and Sustainable Diets, 140 (3): 413–20. doi:10.1016/j.foodchem.2013.01.034; Costello et al. 2019. "The Future of Food from the Sea."

522. Huntington, T., and M.R. Hasan, eds. 2009. "Fish as Feed Inputs for Aquaculture: Practices, Sustainability and Implications." FAO Fisheries and Aquaculture Technical Paper no. 518. Rome: Food and Agriculture Organization of the United Nations. https://www.researchgate.net/profile/Mohammad_Hasan22/publication/336030732_Fish_as_feed_inputs_for_aquaculture_practices_sustainability_and_implications/links/5d8b8f80a6fdcc255499d9e9/Fish-as-feed-inputs-for-aquaculture-practices-sustainability-and-implications.pdf#page=19.

523. Costello et al. 2020. "The Future of Food from the Sea" (*Nature*).

524. FAO, ed. 2018. *The State of World Fisheries and Aquaculture 2018*.

525. Widjaja et al. 2020. "Illegal, Unreported and Unregulated Fishing and Associated Drivers."

526. Pew Charitable Trusts. 2019. "International Fisheries Managers' Response to Performance Reviews Insufficient."

527. Costello et al. 2019. "The Future of Food from the Sea."

528. Inniss et al. 2016. "The First Global Integrated Marine Assessment."

529. FAO, ed. 2018. *The State of World Fisheries and Aquaculture 2018*.

530. FAO. 2017. "FAO Regional Office for Europe and Central Asia: Losses in Fisheries and Aquaculture Tackled at Global Fishery Forum." 14 September. http://www.fao.org/europe/news/detail-news/en/c/1037271/.

531. FAO. 2017. "FAO Regional Office for Europe and Central Asia."

532. Costello et al. 2016. "Global Fishery Prospects under Contrasting Management Regimes."

533. Costello et al. 2016. "Global Fishery Prospects under Contrasting Management Regimes.

534. Costello et al. 2019. "The Future of Food from the Sea."

535. Costello et al. 2019. "The Future of Food from the Sea."

536. Chung, I.K., J. Beardall, S. Mehta, D. Sahoo and S. Stojkovic. 2011. "Using Marine Macroalgae for Carbon Sequestration: A Critical Appraisal." *Journal of Applied Phycology* 23 (5): 877–86. doi:10.1007/s10811-010-9604-9; N'Yeurt, A. de R., D.P. Chynoweth, M.E. Capron, J.R. Stewart and M.A. Hasan. 2012. "Negative Carbon via Ocean Afforestation." *Process Safety and Environmental Protection* 90 (6): 467–74. doi:10.1016/j.psep.2012.10.008; Sondak, C.F.A., P.O. Ang, J. Beardall, A. Bellgrove, S.M. Boo, G.S. Gerung, C.D. Hepburn et al. 2017. "Carbon Dioxide Mitigation Potential of Seaweed Aquaculture Beds (SABs)." *Journal of Applied Phycology* 29 (5): 2363–73. doi:10.1007/s10811-016-1022-1; Duarte, C.M., J. Wu, X. Xiao, A. Bruhn and D. Krause-Jensen. 2017. "Can Seaweed Farming Play a Role in Climate Change Mitigation and Adaptation?" *Frontiers in Marine Science* 4. doi:10.3389/fmars.2017.00100; Capron, M.E., Z. Moscicki, R. Blaylock, C. Sullivan, K. Lucas, I. Tsukrov, M.D. Chambers et al. 2018. "Ocean Forests: Breakthrough Yields for Macroalgae." In *OCEANS 2018 MTS/IEEE Charleston*, 1–6. doi:10.1109/OCEANS.2018.8604586; Froehlich, H.E., J.C. Afflerbach, M. Frazier and B.S. Halpern. 2019. "Blue Growth Potential to Mitigate Climate Change through Seaweed Offsetting." *Current Biology* 29 (18): 3087–93.e3. doi:10.1016/j.cub.2019.07.041; Brooke, C.G., B.M. Roque, N. Najafi, M. Gonzalez, A. Pfefferlen, V. DeAnda, D.W. Ginsburg et al. 2018. "Evaluation of the Potential of Two Common Pacific Coast Macroalgae for Mitigating Methane Emissions from Ruminants." *BioRxiv*, October, 434480. doi:10.1101/434480; Roque, B.M., C.G. Brooke, J. Ladau, T. Polley, L.J. Marsh, N. Najafi, P. Pandey et al. 2019. "Effect of the Macroalgae *Asparagopsis taxiformis* on Methane Production and Rumen Microbiome Assemblage." *Animal Microbiome* 1 (1): 3. doi:10.1186/s42523-019-0004-4; Machado, L., M. Magnusson, N.A. Paul, R. Kinley, R. de Nys and N. Tomkins. 2016. "Dose-Response Effects of *Asparagopsis taxiformis* and *Oedogonium* sp. on in Vitro Fermentation and Methane Production." *Journal of Applied Phycology* 28 (2): 1443–52. doi:10.1007/s10811-015-0639-9.

537. Froehlich et al. 2019. "Blue Growth Potential to Mitigate Climate Change through Seaweed Offsetting."

538. Capron et al. 2018. "Ocean Forests"; Oilgae. 2010. *Oilgae Guide to Fuels from Macroalgae*. Tamil Nadu, India. https://arpa-e.energy.gov/sites/default/files/Oilgae%20Guide%20to%20Fuels%20from%20Macroalgae%202010.pdf; Czyrnek-Delêtre, M.M., S. Rocca, A. Agostini, J. Giuntoli and J.D. Murphy. 2017. "Life Cycle Assessment of Seaweed Biomethane, Generated from Seaweed Sourced from Integrated Multi-trophic Aquaculture in Temperate Oceanic Climates." *Applied Energy* 196 (June): 34–50. doi:10.1016/j.apenergy.2017.03.129; Benzie, J.A.H., T.T.T. Nguyen, G. Hulata, D. Bartley, R. Brummett, B. Davy, M. Halwart et al. 2012. "Promoting Responsible Use and Conservation of Aquatic Biodiversity for Sustainable Aquaculture Development." In *Farming the Waters for People and Food: Proceedings of the Global Conference on Aquaculture 2010*, 337–83. Phuket, Thailand: Food and Agriculture Organization of the United Nations, Network of Aquaculture Centers in Asia. https://www.researchgate.net/profile/Matthias_Halwart/publication/263569545_Supporting_farmer_innovations_recognizing_indigenous_knowledge_and_disseminating_success_stories/links/0046353b412ffc6050000000/Supporting-farmer-innovations-recognizing-indigenous-knowledge-and-disseminating-success-stories.pdf#page=349; Loureiro, R., C.M.M. Gachon and C. Rebours. 2015. "Seaweed Cultivation: Potential and Challenges of Crop Domestication at an Unprecedented Pace." *New Phytologist* 206 (2): 489–92. doi:10.1111/nph.13278.
539. Costello et al. 2019. "The Future of Food from the Sea."
540. FOLU. 2019. *Growing Better*.
541. FOLU. 2019. *Growing Better*.
542. FOLU. 2019. *Growing Better*.
543. FOLU. 2019. *Growing Better*.
544. Halpern, B.S., S.E. Lester and J.B. Kellner. 2009. "Spillover from Marine Reserves and the Replenishment of Fished Stocks." *Environmental Conservation* 36 (4): 268–76. doi:10.1017/S0376892910000032; da Silva, I.M., N. Hill, H. Shimadzu, A.M.V.M. Soares and M. Dornelas. 2015. "Spillover Effects of a Community-Managed Marine Reserve." *PLOS ONE* 10 (4): e0111774. doi:10.1371/journal.pone.0111774.
545. FOLU. 2019. *Growing Better*.
546. FOLU. 2019. *Growing Better*.
547. Rogers et al. 2020. "Critical Habitats and Biodiversity."
548. Costello et al. 2019. "The Future of Food from the Sea."
549. FOLU. 2019. *Growing Better*.
550. Woods Hole Oceanographic Institution. n.d. "Ocean Twilight Zone." Blog. https://www.whoi.edu/know-your-ocean/ocean-topics/ocean-life/ocean-twilight-zone/. Accessed 18 August 2020.
551. Woods Hole Oceanographic Institution. n.d. "Ocean Twilight Zone."
552. Stubgaard, K. 2020. "About the MEESO Project." 25 May. https://www.meeso.org/about.
553. Hoegh-Guldberg et al. 2019. "The Ocean as a Solution to Climate Change."
554. IRENA. 2019. "Global Energy Transformation: A Roadmap to 2050 (2019 Edition)." Abu Dhabi: International Renewable Energy Agency. https://www.irena.org/publications/2019/Apr/Global-energy-transformation-A-roadmap-to-2050-2019Edition.
555. Dutton, A.S.P., C.C. Sullivan, E.O. Minchew, O. Knight and S. Whittaker. 2019. "Going Global: Expanding Offshore Wind to Emerging Markets." 143162. World Bank. http://documents.worldbank.org/curated/en/716891572457609829/Going-Global-Expanding-Offshore-Wind-To-Emerging-Markets.
556. Cohen, A. 2019. "As Global Energy Demand Grows, So Does Appetite for Offshore Wind." *Forbes*, 26 March. https://www.forbes.com/sites/arielcohen/2019/03/26/as-global-energy-demands-grows-so-does-appetite-for-offshore-wind/.
557. Cohen. 2019. "As Global Energy Demand Grows, So Does Appetite for Offshore Wind"; Buckley, T., and K. Shah. 2018. "IEEFA Update: Offshore Wind Power, the Underexplored Opportunity That Could Replace Coal in Asia." *Institute for Energy Economics & Financial Analysis* (blog), 30 August. https://ieefa.org/offshore-wind-power-the-underexplored-opportunity-to-replace-coal-in-asia/.
558. Nghiem, A., and I. Pineda. 2017. "Wind Energy in Europe: Scenarios for 2030." Brussels: Wind Europe. https://windeurope.org/wp-content/uploads/files/about-wind/reports/Wind-energy-in-Europe-Scenarios-for-2030.pdf.
559. Global Wind Energy Council. 2019. "The Growth of the Global Offshore Wind Market Will Be Driven by Asia." Blog, 23 September. https://gwec.net/the-growth-of-the-global-offshore-wind-market-will-be-driven-by-asia/.
560. International Chamber of Shipping. n.d. "Shipping and World Trade." https://www.ics-shipping.org/shipping-facts/shipping-and-world-trade. Accessed 18 August 2020.
561. UNCTAD. 2020. *Review of Maritime Transport 2019*. New York: United Nations. https://unctad.org/en/PublicationsLibrary/rmt2019_en.pdf.
562. UNCTAD. 2019. *Review of Maritime Transport 2018*. New York: United Nations. https://unctad.org/en/PublicationsLibrary/rmt2018_en.pdf.
563. IMO. 2015. "Third IMO Greenhouse Gas Study 2014," 3.
564. Hoegh-Guldberg et al. 2019. "The Ocean as a Solution to Climate Change."
565. Olmer et al. 2017. "Greenhouse Gas Emissions from Global Shipping, 2013–2015."
566. ETC. n.d. "Mission Possible."
567. Cofala, J., M. Amann, J. Borken-Kleefeld, A. Gomez-Sanabria, C. Heyes, G. Kiesewetter, R. Sander et al. 2018. "The Potential for Cost-Effective Air Emission Reductions from International Shipping through Designation of Further Emission Control Areas in EU Waters with Focus on the Mediterranean Sea." Vienna: International Institute for Applied Systems Analysis. https://www.cittadiniperlaria.org/wp-content/uploads/2019/04/Shipping_emissions_reductions_main.pdf.
568. GEF-UNDP-IMO GloBallast Partnerships. 2017. "The GloBallast Story."
569. Locke, A., D.M. Reid, W.G. Sprules, J.T. Carlton and H.C. van Leeuwen. 1991. "Effectiveness of Mid-ocean Exchange in Controlling Freshwater and Coastal Zooplankton in Ballast Water"; Locke, A., D.M. Reid, H.C. van Leeuwen, W.G. Sprules and J.T. Carlton. 1993. "Ballast Water Exchange as a Means of Controlling Dispersal of Freshwater Organisms by Ships." *Canadian Journal of Fisheries and Aquatic Sciences* 50 (10): 2086–93. doi:10.1139/f93-232; Gollasch, S. 1996. *Untersuchungen des Arteintrages durch den internationalen Schiffsverkehr unter besonderer Berücksichtigung nichtheimischer Arten*. Hamburg: Kovač; Kabler, L.V. 1996. "Ballast Water Invaders: Breaches in the Bulwark." *Aquatic Nuisance Species Digest* 1 (3): 34–35.
570. Subba Rao et al. 1994. "Exotic Phytoplankton from Ship's Ballast Waters."
571. Segee, B.P. 2010. "Whale of Opportunity: Coast Guard Study of Los Angeles/Long Beach Port Access Routes Holds Great Potential for Reducing Ship Strikes within Santa Barbara Channel." *Ecology Law Currents* 37: 58.
572. Kulp, S.A., and B.H. Strauss. 2019. 'New Elevation Data Triple Estimates of Global Vulnerability to Sea-Level Rise and Coastal Flooding'. *Nature Communications* 10 (1): 4844. doi: "https://protect-eu.mimecast.com/s/Ic2sC9g7wfr0jAio6c7w?domain=doi.org" 10.1038/s41467-019-12808-z.

573. Valiela et al. 2001. "Mangrove Forests"; Millennium Ecosystem Assessment (Program), ed. 2005. *Ecosystems and Human Well-Being*; Orth, R.J., T.J.B. Carruthers, W.C. Dennison, C.M. Duarte, J.W. Fourqurean, K.L. Heck, A.R. Hughes et al. 2006. "A Global Crisis for Seagrass Ecosystems." *BioScience* 56 (12): 987–96. doi:10.1641/0006-3568(2006)56[987:AGCFSE]2.0.CO;2; FAO. 2007. "The World's Mangroves, 1980–2005." Thematic study prepared in the framework of the Global Forest Resources Assessment 2005. Rome: Food and Agriculture Organization of the United Nations. http://www.fao.org/3/a1427e/a1427e00.pdf; Waycott, M., C.M. Duarte, T.J.B. Carruthers, R.J. Orth, W.C. Dennison, S. Olyarnik, A. Calladine et al. 2009. "Accelerating Loss of Seagrasses across the Globe Threatens Coastal Ecosystems." *Proceedings of the National Academy of Sciences* 106 (30): 12377–81. doi:10.1073/pnas.0905620106.

574. Kulp, S.A., and B.H. Strauss. 2019. 'New Elevation Data Triple Estimates of Global Vulnerability to Sea-Level Rise and Coastal Flooding'. *Nature Communications* 10 (1): 4844. doi: "https://protect-eu.mimecast.com/s/Ic2sC9g7wfr0jAio6c7w?domain=doi.org" 10.1038/s41467-019-12808-z.

575. Wright, L.D., J.P.M. Syvitski and C.R. Nichols. 2019. "Sea Level Rise: Recent Trends and Future Projections." In *Tomorrow's Coasts: Complex and Impermanent*, edited by L.D. Wright and C.R. Nichols, 47–57. Coastal Research Library. Cham: Switzerland: Springer. doi:10.1007/978-3-319-75453-6_3.

576. Steven, A., K.A. Addo, G. Llewelyn, C.V. Thanh et al. 2020. "Coastal Development: Resilience, Restoration and Infrastructure Requirements." Washington, DC: World Resources Institute. https://www.oceanpanel.org/blue-papers/coastal-development-managing-resilience-restoration-and-infrastructure-coastlines.

577. Gittman, R.K., C.H. Peterson, C.A. Currin, F.J. Fodrie, M.F. Piehler and J.F. Bruno. 2016. "Living Shorelines Can Enhance the Nursery Role of Threatened Estuarine Habitats." *Ecological Applications* 26 (1): 249–63. doi:10.1890/14-0716.

578. Costanza, R., R. de Groot, P. Sutton, S. van der Ploeg, S.J. Anderson, I. Kubiszewski, S. Farber and R.K. Turner. 2014. "Changes in the Global Value of Ecosystem Services." *Global Environmental Change* 26 (May): 152–58. doi:10.1016/j.gloenvcha.2014.04.002; McCauley, D.J. 2006. "Selling Out on Nature." *Nature* 443 (7107): 27–28. doi:10.1038/443027a; Bartha, P., and C.T. DesRoches. 2017. "The Relatively Infinite Value of the Environment." *Australasian Journal of Philosophy* 95 (2): 328–53. doi:10.1080/00048402.2016.1182196.

579. Rockström et al. 2009. "Planetary Boundaries."

580. Wilkinson, C. n.d. "Status of Coral Reefs of the World: 2004." Australian Institute of Marine Science, Global Coral Reef Monitoring Network. http://www.icriforum.org/sites/default/files/scr2004v1-all.pdf. Accessed 12 May 2020.

581. Beck et al. 2018. "The Global Flood Protection Savings Provided by Coral Reefs."

582. Costanza, R., O. Pérez-Maqueo, M.L. Martinez, P. Sutton, S.J. Anderson and K. Mulder. 2008. "The Value of Coastal Wetlands for Hurricane Protection." *AMBIO: A Journal of the Human Environment* 37 (4): 241–48. doi:10.1579/0044-7447(2008)37[241:TVOCWF]2.0.CO;2.

583. Losada, Í.J., P. Menéndez, A. Espejo, S. Torres, P.D. Simal, S. Abad, M.W. Beck et al. 2018. "The Global Value of Mangroves for Risk Reduction." Berlin: The Nature Conservancy. nature.org/GlobalMangrovesRiskReductionSummaryReport.

584. Mehvar, S., T. Filatova, A. Dastgheib, E. De Ruyter van Steveninck and R. Ranasinghe. 2018. "Quantifying Economic Value of Coastal Ecosystem Services: A Review." *Journal of Marine Science and Engineering* 6 (1): 5. doi:10.3390/jmse6010005.

585. McGranahan, G., D. Balk and B. Anderson. 2007. "The Rising Tide: Assessing the Risks of Climate Change and Human Settlements in Low Elevation Coastal Zones." *Environment and Urbanization* 19 (1): 17–37. doi:10.1177/0956247807076960.

586. NOAA Office for Coastal Management. n.d. "Fast Facts: Economics and Demographics." https://coast.noaa.gov/states/fast-facts/economics-and-demographics.html. Accessed 12 May 2020.

587. Bathi, J.R., and H.S. Das. 2016. "Vulnerability of Coastal Communities from Storm Surge and Flood Disasters." *International Journal of Environmental Research and Public Health* 13 (2): 239. doi:10.3390/ijerph13020239.

588. Giannico, G., and J.A. Souder. 2005. "Tide Gates in the Pacific Northwest." Oregon State University; Martínez, M.L., G. Mendoza-González, R. Silva-Casarín and E. Mendoza-Baldwin. 2014. "Land Use Changes and Sea Level Rise May Induce a 'Coastal Squeeze' on the Coasts of Veracruz, Mexico." *Global Environmental Change* 29 (November): 180–88. doi:10.1016/j.gloenvcha.2014.09.009; Tessler, Z.D., C.J. Vörösmarty, I. Overeem and J.P.M. Syvitski. 2018. "A Model of Water and Sediment Balance as Determinants of Relative Sea Level Rise in Contemporary and Future Deltas." *Geomorphology*, Resilience and Bio-geomorphic Systems—Proceedings of the 48th Binghamton Geomorphology Symposium (March): 209–20.

589. Vörösmarty, C.J., M. Meybeck, B. Fekete, K. Sharma, P. Green and J.P.M. Syvitski. 2003. "Anthropogenic Sediment Retention: Major Global Impact from Registered River Impoundments." *Global and Planetary Change* 39 (1): 169–90. doi:10.1016/S0921-8181(03)00023-7.

590. Vörösmarty et al. 2003. "Anthropogenic Sediment Retention."

591. Ericson, J.P., C.J. Vörösmarty, S.L. Dingman, L.G. Ward and M. Meybeck. 2006. "Effective Sea-Level Rise and Deltas: Causes of Change and Human Dimension Implications." *Global and Planetary Change* 50 (1): 63–82. doi:10.1016/j.gloplacha.2005.07.004.

592. Forbes, H., K. Ball and F. McLay. n.d. *Natural Flood Management Handbook*. Stirling, UK: Scottish Environment Protection Agency. https://www.sepa.org.uk/media/163560/sepa-natural-flood-management-handbook1.pdf. Accessed 12 May 2020.

593. Hoegh-Guldberg et al. 2019. "The Ocean as a Solution to Climate Change."

594. Ecological Tourism in Europe, UN Educational, Scientific and Cultural Organization and UN Environment Programme. n.d. "Sustainable Tourism Development in UNESCO Designated Sites in South-Eastern Europe." http://portal.unesco.org/en/files/45338/12417872579Introduction_Sustainable_Tourism.pdf/Introduction_Sustainable_Tourism.pdf. Accessed 7 May 2020.

595. UN World Tourism Organization (UNWTO). n.d. "Global and Regional Tourism Performance." https://www.unwto.org/global-and-regional-tourism-performance. Accessed 11 May 2020; Inniss et al. 2016. "The First Global Integrated Marine Assessment"; UNWTO, ed. 2011. *Tourism towards 2030 / Global Overview: Advance Edition Presented at UNWTO 19th General Assembly—10 October 2011*. doi:10.18111/9789284414024.

596. Inniss et al. 2016. "The First Global Integrated Marine Assessment"; TNS Political and Social. 2014. "Preferences of Europeans towards Tourism." Flash Eurobarometer 392. European Commission. https://ec.europa.eu/commfrontoffice/publicopinion/flash/fl_392_sum_en.pdf.

597. Spalding, M., L. Burke, S.A. Wood, J. Ashpole, J. Hutchison and P. zu Ermgassen. 2017. "Mapping the Global Value and Distribution of Coral Reef Tourism." *Marine Policy* 82 (August): 104–13. doi:10.1016/j.marpol.2017.05.014.

598. Spalding et al. 2017. "Mapping the Global Value and Distribution of Coral Reef Tourism."

599. Kennedy, S. n.d. "2019 Cruise Trends & Industry Outlook." Cruise Lines International Association. https://cruising.org/-/media/research-updates/research/clia-2019-state-of-the-industry-presentation-(1).pdf. Accessed 12 May 2020.

600. Honey, M., and David Krantz. 2007. "Global Trends in Coastal Tourism." Stanford, UK, and Washington, DC: Center on Ecotourism and Sustainable Development, World Wildlife Fund. https://tamug-ir.tdl.org/bitstream/handle/1969.3/29198/global_trends_in_coastal_tourism_by_cesd_jan_08_lr.pdf?sequence=1.

601. World Bank. 2009. "Environment Matters at the World Bank: Valuing Coastal and Marine Ecosystem Services." http://documents.worldbank.org/curated/en/593291468150870756/Environment-matters-at-the-World-Bank-valuing-coastal-and-marine-ecosystem-services.

602. van Acoleyen, M., I. Laureysens, S. Lambert, L. Raport, C. van Sluis, B. Kater, E. van Onselen et al. n.d. *Marine Litter Study to Support the Establishment of an Initial Quantitative Headline Reduction Target: SFRA0025*. ARCADIS, European Commission DG Environment. https://ec.europa.eu/environment/marine/good-environmental-status/descriptor-10/pdf/final_report.pdf. Accessed 12 May 2020.

603. UNCTAD. 2020. “The COVID-19 Pandemic and the Blue Economy.”

604. UNWTO. n.d. “Global and Regional Tourism Performance.”

605. CEA Consulting. n.d. “Funding.” Our Shared Seas. https://oursharedseas.com/2019-update/funding/. Accessed 12 May 2020.

606. UNCTAD. 2019. *World Investment Report 2019: Special Economic Zones*. UN Conference on Trade and Development World Investment Report (WIR). New York: United Nations. doi:10.18356/8a8d05f9-en.

607. Gold, J. 2017. “Tracking Delivery: Global Trends and Warning Signs in Delivery Units.” Institute for Government. https://www.instituteforgovernment.org.uk/sites/default/files/publications/Global%20Delivery%20report.pdf.

608. de Vrees, L. 2019. “Adaptive Marine Spatial Planning in the Netherlands Sector of the North Sea.” *Marine Policy*, February, 103418. doi:10.1016/j.marpol.2019.01.007.

609. Northrop et al. 2020. “A Sustainable and Equitable Blue Recovery to the COVID-19 Crisis.”

610. UN Framework Convention on Climate Change. n.d. “The Paris Agreement.” https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement. Accessed 12 May 2020.

611. UN Framework Convention on Climate Change. n.d. “Paris Agreement: Status of Ratification.” https://unfccc.int/process/the-paris-agreement/status-of-ratification. Accessed 12 May 2020.

612. Climate Analytics and NewClimate Institute. n.d. “Climate Action Track: Governments Still Showing Little Sign of Acting on Climate Crisis—Warming Projections Global Update.” https://climateactiontracker.org/documents/698/CAT_2019-12-10_BriefingCOP25_WarmingProjectionsGlobalUpdate_Dec2019.pdf. Accessed 12 May 2020.

613. Curtis, L. 2019. *Report of the Second Meeting of the Parties to the Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing*. FAO Fisheries and Aquaculture Report FIAO/R1272. Santiago, Chile: Food and Agriculture Organization of the United Nations. http://www.fao.org/3/ca5757en/CA5757EN.pdf.

614. IMO. n.d. “The Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships.” http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/The-Hong-Kong-International-Convention-for-the-Safe-and-Environmentally-Sound-Recycling-of-Ships.aspx. Accessed 12 May 2020.

615. IMO. n.d. “The Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships.”

616. IMO. n.d. “The Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships.”

617. IMO. 2019. “What’s New during 2019.” http://www.imo.org/en/MediaCentre/WhatsNew/Pages/Archive-2019.aspx. Accessed 12 May 2020.

618. Gottlieb, H.M., and M. Conathan. 2019. “The Path to a High Seas Treaty.” Aspen Institute. 18 April. https://www.aspeninstitute.org/blog-posts/the-path-to-a-high-seas-treaty/.

619. Gottlieb and Conathan. 2019. “The Path to a High Seas Treaty.”

620. Secretariat of the Convention on Biological Diversity. 2012. Introduction to Convention on Biological Diversity. 16 January. https://www.cbd.int/intro/.

621. Global Ocean Commission. 2014. “From Decline to Recovery: A Rescue Package for the Global Ocean.” https://www.iucn.org/sites/dev/files/import/downloads/goc_full_report_1.pdf.

622. Bridgewater, P. 2016. “The Man and Biosphere Programme of UNESCO: Rambunctious Child of the Sixties, but Was the Promise Fulfilled?” *Current Opinion in Environmental Sustainability* 19 (April): 1–6. doi:10.1016/j.cosust.2015.08.009.

623. Swilling et al. 2020. “The Ocean Transition.”

624. Swilling et al. 2020. “The Ocean Transition.”

625. Ostrom, E. 2010. “Polycentric Systems for Coping with Collective Action and Global Environmental Change.” *Global Environmental Change* 20 (4): 550–57. doi:10.1016/j.gloenvcha.2010.07.004.

626. Saint-Exupéry, A. 1948. Citadelle. Original text in French: ‘Créer le navire ce n'est point tisser les toiles, forger les clous, lire les astres, mais bien donner le goût de la mer qui est un, et à la lumière duquel il n'est plus rien qui soit contradictoire mais communauté dans l'amour.’

627. Roy, A. 2020. “The Pandemic Is a Portal.” *Financial Times*, 3 April. https://www.ft.com/content/10d8f5e8-74eb-11ea-95fe-fcd274e920ca.

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