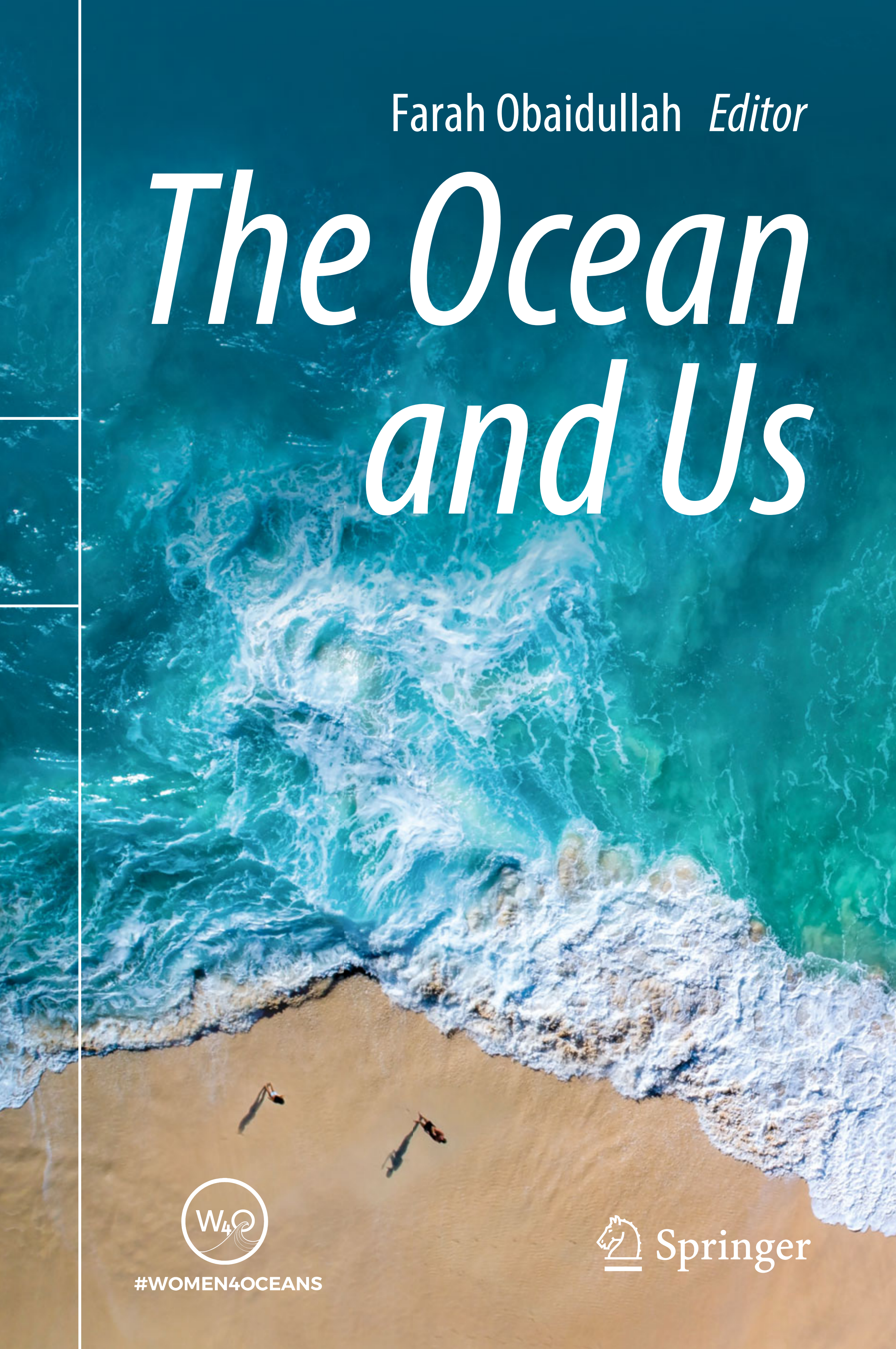
Farah Obaidullah *Editor*

The Ocean and Us



#WOMEN4OCEANS

Springer

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Foreword

"People need to know. You can't care if you don't know, and most people simply don't know". The words come from legendary oceanographer Sylvia Earle. With this in mind: if all the knowledge conveyed in this fantastic book would lead to real action at the political and individual levels, we would save our ocean, our coasts, the climate and ourselves.

Unfortunately, not all knowledge leads to action—a bitter truth that those of us who have engaged in ocean politics for years have experienced first hand. For example, even though scientists, relevant authorities and politicians have known for decades that overfishing is a long-term threat to both the marine environment and to the livelihoods of fisherfolk, it remains absurdly difficult to put in place the necessary legislation and measures to halt it. Within Europe, we made significant progress as part of the reform of the EU Common Fisheries Policy in 2013, when for example fish discarding was banned and overfishing outlawed. That reform, which I was deeply engaged in, would not have been possible without two things: some active politicians on the inside and a strong voice from the public opinion on the outside. If knowledge alone would trigger action, the EU Common Fisheries Policy would never have allowed fish stocks to dwindle and species such as Bluefin tuna, the European eel and cod to become vulnerable to extinction.

Turning back to knowledge—how do we create a public opinion that can actually move a majority of politicians to take action? This book provides almost all the necessary tools for anyone who wants to raise awareness about the ocean, or who simply wants to understand the problems at hand. It is a unique compilation of the accumulated, most recent knowledge about nearly every possible problem or topic of discussion when it comes to the ocean: how we can protect it or how we derive benefits from it. From a diverse range of topics including shipping, fishing, plastic pollution and the aquarium trade, to concepts such as the blue economy and ocean and human health, we get a good overview from experts in easy to follow language. This book enhances our Ocean Literacy—a concept that is gaining importance everywhere.

The Ocean and Us also gives perspectives on whose voices or views dominate in ocean politics. This may lead to a deeper discussion on what I, during my time as a member of the European Parliament and the minister in Sweden continuously asked myself: Why is so little happening, when we know so much already? How can we convince legislators and private companies to take the necessary measures? What is missing when it comes to decision-making?

The facts and figures themselves are clearly not enough to trigger sufficient action, not even when accompanied by sparks of emotion, for instance when we see shocking images of stranded whales with their stomachs full of plastic, or when we watch children marching the streets, demanding a better future, one that is not stolen for greed.

I therefore appreciate that this book also reminds us that there are alternative perspectives that could provide that trigger, or the moral foundation for action. To quote UN Secretary António Guterres, we have come to a point in history where it is either “break-down, or break-through” and where “we need to end our suicidal war with nature”. We need therefore a new human logic, not one of the ruthless exploitation, but one of a respectful relationship with nature, something that comes natural to many people and many cultures.

This book touches upon the spiritual value of the ocean. Reminding us of how we all belong to the living world around us, to infinity, how beautiful and forceful it is and that we are part of it. Very often I use the Sufi poet Rumi’s quote that tells us all this in this one brilliant line:

“You are not a drop in the ocean. You are the entire ocean in one drop”.

Stockholm, Sweden
May 2022

Isabella Lövin
Deputy Prime Minister of Sweden
from 2016 to 2021
Sweden’s Minister for the Environment
2019 to 2021
Sweden’s Minister for International
Development Cooperation 2014 to
2019, Member of the European
Parliament 2009–2014

Preface

Snorkelling in the shallows of a tucked away bay in Gabon, aged seven, I spotted an octopus in a glass bottle—this was in the mid-1980s, before the tsunami of plastic pollution began flooding our oceans and beaches. Thinking that this adorable sentient being was trapped, my reflex was to rescue it. I carefully coaxed it out of the bottle, only to find it went straight back in. I understood then that nature has a perfect plan. I know now that we are a part of that plan and that if we are to thrive we must learn to listen to nature and accept our inherent and integral position in the natural world.

Our planet is an ocean planet. The ocean covers over 70% of the earth's surface and 90% of the planet's habitable space. Until recently in human history, the ocean was largely inaccessible to human endeavours. As such, it remained the stuff of fantasy, awe and mystery. To this day, much of the ocean remains unexplored. Advances in technology are allowing us to discover more species and understand the critical role the ocean plays in sustaining life on earth as we know it. It is estimated that the ocean is home to several million species, most of which have yet to be discovered. But we are losing species faster than we can discover them. In fact, we have already lost an estimated two-thirds of global wildlife.

Our ignorance of the ocean has led and continues to lead to its exploitation. We are barrelling towards the point of no return when it comes to the health of our planet and therefore ourselves. Climate change is affecting every aspect of the natural world, pushing planetary boundaries beyond repair within human time scales. We are fishing out more than the ocean can replenish, treating the ocean as a dumping ground for everything from plastics to nuclear waste and diminishing the ocean's ability to buffer us against the worst effects of human-induced climate change. How are we so at odds with the natural world? Is it that we can't keep up with our own fast-paced industrialization, never pausing to reflect on our place in the world? As I write this, there are a handful of companies pushing to open the international seabed to mining. An emerging industry that if allowed to go ahead will irreversibly destroy life in the deep ocean, with detrimental consequences to ocean functions, including disturbing locked-away carbon.

It takes awareness and courage to turn things around. My observation after 45 laps around the sun is that people are curious beings. We want to understand who we are, what our purpose is and how we can collectively make this world a better place for ourselves and those that come after us. I chose a path of advocacy and activism to bring about awareness of the state of the ocean and importantly to change things. I am a strong believer in our impetus to protect what we love. This all begins with knowledge. We cannot love and therefore protect what we do not know.

Over the years, I have been asked time and again by people outside the ocean community about where they can learn about the ocean and what they can do to help protect it. I was never able to point to a single comprehensive easy to follow resource for everyone with an interest in the ocean. The only way I could think to remedy that was to produce a book: a one-stop shop covering our contemporary understanding of the ocean and all the ways our lives interact with it.

The chapters that follow do not pretend to cover everything. They offer you, the reader, a glimpse into a whole field of knowledge, hopefully awakening your curiosity, awareness and with that your ability to act.

Our knowledge of the ocean is continuously increasing. Even in the time that it has taken to produce this book, there are new and exciting areas of ocean research, enterprise and philosophy that could warrant their own chapters. For example, what does our future relationship with the ocean look like? As it stands, 64% of the ocean makes up our global commons. They do not belong to any one nation but constitute almost half of our planet. Will we start inhabiting this space, on the surface and even in the blue realm beneath it? How will we govern activities in future? We are facing a multitude of crises from climate change to biodiversity loss and with that existential threats to human health through for example wars, displacement of people, famine and pandemics. This all stems from our disconnect from nature, and as we move forward we must ask ourselves whether our current systems, including the way we govern and manage the ocean, are up to the task of addressing these interlinked crises.

Each chapter is written by an expert, providing an overview of the topic at hand and offering suggestions for what you can do to help improve ocean health. Whilst our individual actions are important, for example reducing our carbon footprints as well as being mindful of our consumer choices, of seafood and all our purchases, equally important is the power, if you have it, of voting. We must continue to push for change at the level of our elected officials, regionally, nationally and internationally and hold them to account.

I hope you will benefit from this resource and that you will draw inspiration from the many different voices and perspectives offered. I deliberately chose to pull together the expertise from perspectives other than just my own, as I believe that every action we take builds on the action and knowledge of others. We cannot shape the world alone. We must work together, building bridges, finding resolve in our human diversity, learning from one another and embracing our place within nature's perfect plan.

> Individually, we are one drop. Together, we are an ocean.
>
> —Ryunosuke Satoro

The Hague, The Netherlands Farah Obaidullah
2022

Acknowledgments

The idea for *The Ocean and Us* was inspired by questions I received from interested non-expert women in the Women4Oceans community who want to learn more about the ocean. After a telephone conversation in December 2019 with Anne MacDiarmid, a nurse based in Canada, whom I have never met before, I was resolved to produce this book. Talking to Anne, I realised there was a need to make information about the ocean more widely available, particularly to those who do not work in the ocean space, but who, out of despair for what we are doing to the ocean and our planet, want to learn about the ocean so that they are empowered to take action.

From conception to publication, this book took almost three years to complete. Inviting, confirming and chasing experts to contribute chapters proved to be quite the task, particularly during a time of a global pandemic. I could not have done it without the help and support of Valeria Teloni and Angela Martin. Valeria helped the production of this book, instilling structure in our progress. Both Angela and Valeria provided support in terms of finding practical ways forward when we hit bumps along the way, were there as sparring partners, as well as helping out with chasing and in some cases reviewing contributions.

I would further like to thank Zoé Winck for helping to compile the section on Inspiring Voices, Mariam Ninidze, for helping with marketing and social media during her time as an intern with Women4Oceans, Ruth Leeney for her insights and help in the early stages of production, Iris Maertens for standing ready with a design option for the book cover as well as infographics, Laura Ferris for reviewing some of the early chapter submissions, as well as being a supportive friend and helping develop promotional ideas such as the Coffee Challenge. Heartfelt thanks go Julia Brennan and Linda Cabot for their kind donations to the making of this book—a boost to my own confidence in seeing this project through.

This book would not exist without the contributions of all the authors named in the book. Thank you for offering your time and expertise and for having faith in this project.

Finally, my infinite gratitude goes to my parents: Rita and Khurshid Obaidullah. My parents read through every chapter ensuring that they passed the "lay-person" check. They asked for clarifications, provided edits, suggestions and supported me continuously throughout this journey, as well as every aspect of my life!

The Ocean and Us is the product of each and every one that provided contributions, help and support. Thank you!

Note to the Reader

- Each chapter is written by a different author and covers a different aspect of our relationship with the ocean. Therefore, expect the style as well as level of technicality to vary. American, British and International English are used.
- To keep the subject matter easy to follow, we opted to remove references as you might see them in a scientific publication. However, each chapter offers suggestions for further reading. The final chapter (Chap. 32) is an exception to this rule. Given the subject matter, the authors felt more comfortable providing the references as they wrote.
- You may notice that all the authors are women. This was a deliberate choice which I hope will contribute to mainstreaming women and gender minorities in ocean science and conservation.

A little knowledge that acts is worth infinitely more than much knowledge that is idle.
~ Kahlil Gibran

Action is the antidote to despair.
~ Joan Baez

If you want to go fast, go alone. If you want to go far, go together.
~ African Proverb

Fight for the things that you care about, but do it in a way that will lead others to join you.
~ Ruth Bader Ginsburg

Contents

About the Editor

Farah Obaidullah Ocean Advocate, Consultant and Founder Women4Oceans.

I have been passionate about the ocean since as far back as I can remember. My family moved to live by the North Sea when I was just under three years old. The ever-changing seascape instilled a deep sense of awe, mystery and reverence in me. I also spent some of my childhood in Gabon, West Africa. The tropical Atlantic Ocean introduced me to a whole new world of colourful fishes, marine mammals, white sand beaches and the thriving ecosystems of mangroves and rainforests. I was literally in paradise. Throughout my formative years, my parents were instrumental in shaping my passion for the ocean; not only because of the beaches and coasts they took me to, but importantly because they encouraged me to follow my curiosity. At the age of seven, whilst in Gabon, I became acutely aware of the finite resources of our planet. The never ending stream of logs floating down the river to the ocean, ready for export to Europe and North America, made me realise that one day the forest would be gone. As a teenager I worked in a local aquarium, learning to care for animals and educating the visiting public. It also revealed to me a dark side of the industry in terms of marine animal welfare. I went on to study biology as an undergraduate with a focus on the ocean, followed by a Masters of Science in Environmental Technology in 1998, where my thesis focused on climate change and the ocean. Both my degrees are from Imperial College in London.

My career started off as an environmental consultant. My job allowed me to travel extensively throughout

Europe, Azerbaijan and South Africa. I visited offshore oil and gas platforms as well as facilities on land. I saw with my own eyes the devastation of oil extraction to wild spaces and communities. In 2004, I redirected my career towards my passion for the ocean. I entered the non-profit world and worked for several ocean-focused NGOs. My longest stint was with Greenpeace. Over the last 18 years working for the ocean, I have travelled the world, observing both the beauty of the ocean and the terrible things that we are inflicting upon it. Among my achievements, I have executed campaigns to end destructive fishing, led expeditions at sea, worked with affected communities, lobbied for ocean protection, and been involved in exposing fish crimes, including labour abuse at sea. In addition to putting together this book, I work on various ocean projects. One of the current campaigns I work on, together with a global community of ocean organisations, civil society groups, scientists and even businesses, is to secure a moratorium on deep-sea mining. Deep-sea mining is an emerging threat that if allowed to go ahead will cause irreversible damage to life in the ocean, have unknown consequences on the systems that support life on earth and risks disturbing locked-away carbon.

I am biracial and bicultural and consider myself a citizen of the world. I strongly believe that by embracing our human diversity, we can turn the tide for our ocean planet. It is this belief that compelled me to set up Women4Oceans and to produce *The Ocean and Us*. I have returned to live by the North Sea in the Netherlands.

Part I
Climate Change and the Ocean

Chapter 1
Introduction to Climate Change

Helen S. Findlay

This section focuses on climate change and the ocean. To understand the impacts and processes described in the following chapters, and their relevance to climate change, it is important to understand exactly what is meant by the term "climate change". This chapter outlines the concept of climate change and provides examples of scientific observations which are used to inform the international community and governments. It provides key points from the latest reports and projections of future changes.

The following chapters cover the physical and chemical impacts of climate change, such as ocean acidification, ocean warming and reduced oxygen in the ocean, and how these changing conditions affect life in the ocean. The section will also look at three ways that ocean life interacts with climate through elemental cycles. These include photosynthesis and stabilisation of soils by plants; trophic and behavioural transfer of carbon by plants and animals and animal behaviours that provide nutrients which in turn enable photosynthesis by plants.

Climate Change

Climate change is a change in the state of the climate that can be scientifically identified and that persists for long periods of time (decades or more). The Earth's physical and chemical properties and its position in the solar system determine the climate we experience. The sun provides the main source of heat for Earth's climate in the form of solar energy. Some of that incoming solar energy is reflected back out to space, while the rest is absorbed by the gases that surround the planet (the Earth's atmosphere) as well as the Earth's surface. Much of the energy absorbed by

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the Earth's surface is released again as heat, which can again be absorbed by the atmosphere, and some also returns back out to space. Any change in the balance of incoming solar energy and outgoing heat energy will change the Earth's climate. The atmosphere contains certain gases that are very good at capturing heat energy, commonly known as "greenhouse" gases. As more of these greenhouse gases are added into the atmosphere, more heat is held there, resulting in a warming of the planet. These gases include water vapour, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Without these greenhouse gases, the Earth's surface would be much colder than it is today.

The balance of greenhouse gases in the atmosphere is affected by both natural processes and human activities. Natural processes include forest fires and volcanic activity; over thousands of years volcanoes have caused significant changes in climate. However, since the Industrial Revolution in Western Europe and North America (from about 1760 to 1840), human activity has added more greenhouse gases into the atmosphere than natural processes. The additional gases added by human activity have resulted in climate change across the planet, with an overall warming trend. Human activities, such as burning fossil fuels and cement production, are presently releasing about 10 billion tonnes of carbon (C) each year which remains in the atmosphere as CO_2. Changes in land use also affect the balance of greenhouse gases. For example, cutting down a forest adds CO_2 to the atmosphere in several ways: (1) the tree is no longer actively removing CO_2 from the atmosphere through photosynthesis, (2) the tree is no longer physically stopping the soil surface from releasing the CO_2 it had absorbed, (3) clearing forests is usually carried out either by burning or by using fossil fuel run machinery, both of which add CO_2 to the atmosphere. Furthermore, new activities on the land may increase the release of greenhouse gases, such as replacing a forest with a cattle farm which adds CH_4 to the atmosphere as well as CO_2.

Scientific Observations

Greenhouse gases in the atmosphere are measured around the world. The Mauna Loa Observatory in Hawaii has the longest record for direct measurement of atmospheric CO_2, first recording a full year of data in 1959. Their data shows that the concentration of CO_2 in the atmosphere has increased by 30% between 1959 and 2021, rising from 316 parts per million (ppm) in 1959 to more than 419 ppm in 2021 (annual average 416 ppm). By measuring CO_2 concentration in ice cores, we can see that over the past 800,000 years, atmospheric CO_2 concentration ranged between 170 and 300 ppm. This range has never been exceeded despite large climate fluctuations throughout the many ice age cycles (periods with and without year-round ice in polar regions).

As well as increases in greenhouse gas concentrations, temperature measurements made over the last 100 years show that global temperatures are increasing. The average temperature of the air close to the Earth's surface has risen by about 1 °C since 1900.

A polar bear mother and her young on sea ice, Svalbard. *Credit* Larissa Beumer/Greenpeace

The United Nations: Gathering Scientific Information and Delivering Action

The physical implications of adding CO_2 into the atmosphere from burning of fossil fuels have been known about since the early 1900s, with articles and newspaper reports on the subject as early as 1912. However, it was not until the 1980s that environmental concern began to result in global action.

In the late 1980s, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) created the Intergovernmental Panel on Climate Change (IPCC) to provide scientific information to governments in order for them to develop climate policies. The IPCC gathers scientific evidence from thousands of published scientific papers using a team of international experts. These scientists summarise the findings in reports about the state of knowledge on climate change: its causes, potential impacts and options to respond (mitigation and adaptation). The first assessment report (AR1) was published in 1990.

In response to the AR1 and after rising concern about the human impacts on the climate, the United Nations Framework Convention on Climate Change (UNFCCC) was established in 1994. The ultimate objective of the convention is to stabilise greenhouse gas concentrations "at a level that would prevent dangerous anthropogenic (human induced) interference with the climate system […] such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner".

Today, there are 197 countries that have ratified the convention. These countries are called "Parties to the Convention" and by ratifying the convention agree (non-legally binding) to "adopt policies and measures of mitigation and to report periodically". The Parties meet at a "Conference of Parties" or COP. The first UNFCCC COP was in 1995 in Berlin, Germany, and COPs generally occur at least annually. The COPs provide an opportunity for Parties to report back, negotiate agreements, terms and commitments.

The most significant COP events include the following:

- COP3, 1997, Kyoto, Japan, which resulted in the Kyoto Protocol. This protocol formalised the UNFCCC by "committing industrialised countries and economies in transition to limit and reduce greenhouse gases (GHG) emissions in accordance with agreed individual targets".
- COP21, 2015, Paris, France, which resulted in the Paris Agreement. This agreement was a legally binding agreement with a goal to "limit global warming to well below 2, preferably to 1.5 °C, compared to pre-industrial levels". This agreement was a significant change as, for the first time, it bound all nations to a common undertaking and agreed target level, rather than previously binding just the developed countries. Each nation was tasked to submit plans for climate action, reducing greenhouse gas emissions and building resilience and adaptation, known as Nationally Determined Contributions (NDCs). These NDCs were required to be submitted by 2020.
- COP26, 2021, Glasgow, Scotland, which resulted in the Glasgow Climate Pact. This pact was an agreement between Parties on how to achieve the Paris Agreement (the Paris Agreement Rulebook), as well as detailing "strengthened efforts to build resilience to climate change, to curb greenhouse gas emissions and to provide the necessary finance for both". The Glasgow Climate Pact seeks to increase ambition of NDCs as well as increase the reporting cycle from every 5 years to every year.

Key Scientific Observations from the 2019 IPCC Special Ocean-Focussed Report

In 2019, the IPCC released a special report titled "The Oceans and Cryosphere in a Changing Climate" (SROCC). The cryosphere refers to the parts of the Earth that are frozen, including snow cover, glaciers, ice sheets, ice shelves, icebergs, sea ice, lake ice, river ice, permafrost and seasonally frozen ground. These areas, together with the ocean, play an important role in the overall climate system. This IPCC report detailed the latest observed trends and projections on how climate change is impacting the oceans and the cryosphere.

Observed changes include the following:

- Climate change has led to widespread shrinking of the cryosphere over the last decades due to global warming. Impacts include mass loss from ice sheets and glaciers, reduction in snow cover and reduction in Arctic sea ice extent and thickness.

- The global ocean has warmed continuously since 1970 and has taken up more than 90% of the additional heat in the climate system. Since the 1980s, marine heatwaves have doubled in frequency and increased in intensity. Since the early 1990s, the rate of ocean warming has more than doubled.
- The surface ocean has absorbed more CO_2 resulting in increasing ocean acidification.
- Oxygen has been lost from the upper ocean (surface to 1000 m).
- Global mean sea level is rising, with recent decades seeing an acceleration as a result of increased rates of ice loss from the Greenland and Antarctic ice sheets, as well as continued glacier mass loss and ocean thermal expansion.
- Tropical cyclone winds and rainfall and extreme waves have increased.
- Many marine species have undergone shifts in geographical range and seasonal activity since the 1950s, in response to ocean warming, sea ice changes, ocean acidification, loss of oxygen and changes in their habitats. These shifts have resulted in changes in species composition, abundance and biomass production of ecosystems across the whole globe. Altered interactions have had consequences for ecosystem structure and functioning.
- Coastal ecosystems have been affected by ocean warming, intensified marine heatwaves, acidification, loss of oxygen, salinity intrusion and sea level rise, with consequences for human activity.

Floods in Palangka Raya, Central Kalimantan, 2021. *Credit* Pram/Greenpeace

Modelling Future Projections

Computer models are simulations of the Earth's systems, and they allow scientists to investigate past, present and future climate. They range in complexity by including physical, biological and chemical processes that contribute and drive climate. Climate models essentially make use of scientific knowledge about how Earth systems function to provide a simulated output that is then tested and validated against observations and data. Once there is confidence in a model's performance against historical data, it can be used to project into the future. In order to project into the future, there needs to be a common set of scenarios that can be used to drive the models.

Climate models are continuously being developed and updated. Global modelling groups coordinate these updates around the schedule of the IPCC reports so that they can release a set of model results, known as "runs", in the lead-up to each report. These coordinated modelling efforts are part of the Coupled Model Intercomparison Project (CMIP). The 2013 IPCC fifth assessment report (AR5) featured climate models from CMIP5, while the 2021 IPCC sixth assessment report (AR6) features new, more sensitive CMIP6 models.

The CMIP5 models use four "Representative Concentration Pathways" (RCPs) as drivers to examine the Earth system response to different future greenhouse gas emissions scenarios. These scenarios—named RCP2.6, RCP4.5, RCP6.0 and RCP8.5—are used to project future changes in greenhouse gas emissions and the resulting impacts on the planet, including ocean warming, acidification, loss of sea ice, loss of ocean oxygen content and sea level rise. RCP8.5 is a high greenhouse gas emission scenario without effective climate change mitigation policies, leading to continued and sustained growth in atmospheric greenhouse gas concentrations. RCP2.6 represents a low greenhouse gas emission, with a high mitigation future that gives a two in three chance of limiting global atmospheric surface warming to below 2 °C from pre-industrial levels by the end of the century, the maximum target set by the 2015 Paris Agreement.

In the lead-up to the IPCC AR6, the energy modelling community developed a new improved set of emissions scenarios driven by different socio-economic assumptions, named the "Shared Socio-economic Pathways" (SSPs). The SSPs describe five alternative socio-economic futures: sustainable development (SSP1), middle-of-the-road development (SSP2), regional rivalry (SSP3), inequality (SSP4) and fossil-fuelled development (SSP5). These SSPs are now combined with the RCPs to produce an even more realistic range of options for future scenarios: the RCPs set plausible pathways for greenhouse gas concentrations, while the SSPs set the stage on which reductions in emissions will, or will not, be achieved.

A number of these SSP/RCP combined scenarios were selected to drive climate models for CMIP6, including an update of the four RCP scenarios used in CMIP5, and a number of new scenarios, which give a wider selection of futures for climate scientists to investigate:

- **SSP1-1.9** Scenario with sustainable development, reduced emissions below zero well before year 2100 and global mean warming is limited to 1.5 °C.

- **SSP1-2.6** (**RCP2.6** equivalent) Scenario with sustainable development, reduced emissions below zero well before year 2100 and global mean warming is limited to 2 °C.
- **SSP4-3.4** Scenario of inequality, reduced emissions below zero before year 2100, but fail to limit warming to 2 °C.
- **SSP5-3.4OS** Overshoot scenario with fossil fuel development until year 2040, then rapidly decline in emissions using carbon removal technology.
- **SSP2-4.5** (**RCP4.5** equivalent) Scenario with middle-of-the-road development and modest emissions reductions.
- **SSP4-6.0** (**RCP6.0** equivalent) Scenario with middle-of-the-road development and some emissions reductions.
- **SSP3-7.0** Scenario of regional rivalry, with no emissions reduction and emissions nearly double year 2018 levels by year 2100.
- **SSP5-8.5** (**RCP8.5** equivalent) Scenario of continued fossil fuel development and no reduction in emissions. This scenario is now quite unlikely thanks to the commitments made to the Paris Agreement in 2018.

What Do These Scenarios Mean for the Ocean?

Although this suite of new scenarios exists, most studies still primarily focus on the RCP equivalent scenarios (SSP1-2.6, SSP2-4.5, SSP4-6.0 or SSP3-7.0 and SSP5-8.5). The projections for changes in the main physical and chemical ocean properties for the year 2100 under the different scenarios (where information is available) are outlined in Table 1.1 and Fig. 1.1. More detailed information about changes in the ocean is provided in the following chapters.

In 2021, the IPCC released the first part of the 6th Climate Change Assessment report (AR6) "The Physical Science Basis", which focuses on how all aspects of the Earth's system have been changing. The key messages remained the same in this latest AR6 report compared to the 2019 SROCC report, albeit with increased evidence and certainty around many of the climate change aspects relating to how the ocean has changed in the past but also how this will continue into the future:

> Past GHG emissions since 1750 have committed the global ocean to future warming (*high confidence*). Over the rest of the twenty-first century, likely ocean warming ranges from 2–4 (SSP1-2.6) to 4–8 times (SSP5-8.5) the 1971–2018 change. Based on multiple lines of evidence, upper ocean stratification (*virtually certain*), ocean acidification (*virtually certain*) and ocean deoxygenation (*high confidence*) will continue to increase in the twenty-first century, at rates dependent on future emissions. Changes are irreversible on centennial to millennial time scales in global ocean temperature (*very high confidence*), deep-ocean acidification (*very high confidence*) and deoxygenation (*medium confidence*). (IPCC, 2021)

Table 1.1 Year 2100 values for CO_2 emissions, change in surface air temperature (SAT), sea surface temperature (SST), surface ocean pH, surface ocean oxygen concentration ($[O_2]$), global mean sea level (GMSL) rise and year of first Arctic sea ice (ASI) <1 million km^2 under the different Shared Socio-economic Pathway (SSP) and radiative forcing scenarios

Scenario	Emissions[1]	SAT[2]	SST[3]	pH[4]	$[O_2]$[5]	SLR[6]	ASI[7]
SSP1-1.9	−13.89	1.6 (0.9–2.2)					2036 (2017–2056)
SSP1-2.6	−8.26	2.1 (1.2–2.8)	1.4 ± 0.3	−0.16 ± 0.002	−6.36 ± 2.92	0.47 (0.3–0.64)	2035 (2008–2081)
SSP4-3.4	−14.82	2.8 (1.8–3.8)					
SSP2-4.5	9.68	3.3 (2.0–4.3)	2.1 ± 0.4	−0.26 ± 0.003	−8.14 ± 4.08	0.56 (0.38–0.76)	2041 (2009–2079)
SSP4-6.0	21.93	3.6 (2.6–5.0)					
SSP3-7.0	82.73	4.5 (2.9–6.3)	2.9 ± 0.6	−0.35 ± 0.003	−12.44 ± 4.40		
SSP5-8.5	126.29	5.5 (3.3–7.4)	3.5 ± 0.8	−0.44 ± 0.005	−13.27 ± 5.28	0.76 (0.52–1.05)	2035 (2008–2093)

[1]Amount of CO_2 emissions in the year 2100 (Gigatonnes CO_2) [*cf*. year 2018 = 41.30 Gigatonnes CO_2]. Model ensemble mean value. Carbon Brief
[2]Global mean surface air temperature (SAT) anomaly for period 2090–2100, relative to 1880–1900 period (°C). Model ensemble mean and maximum and minimum values in parenthesis. Carbon Brief
[3]Global mean sea surface temperature (SST) anomaly from 2081–2100, relative to 1850–1900 period (°C). Model ensemble mean ± standard deviation. Kwiatkowski et al. (2020)
[4]Sea surface pH anomaly from 2081–2100, relative to 1850–1900 period. Model ensemble mean ± standard deviation. Kwiatkowski et al. (2020)
[5]Sea surface oxygen (O_2) concentration anomaly from 2081–2100, relative to 1850–1900 period (mmol L^{-1}). Model ensemble mean ± standard deviation. Kwiatkowski et al. (2020)
[6]Sea level rise (SLR) anomaly from 2100, relative to 1986–2005 period. Model ensemble median and 5–95% range in parenthesis. Hermans et al. (2021)
[7]The year that the Arctic sea ice (ASI) area extent is projected to be <1million km^2 for first time. Model ensemble median and maximum and minimum values in parenthesis. SMIP Community (2020).

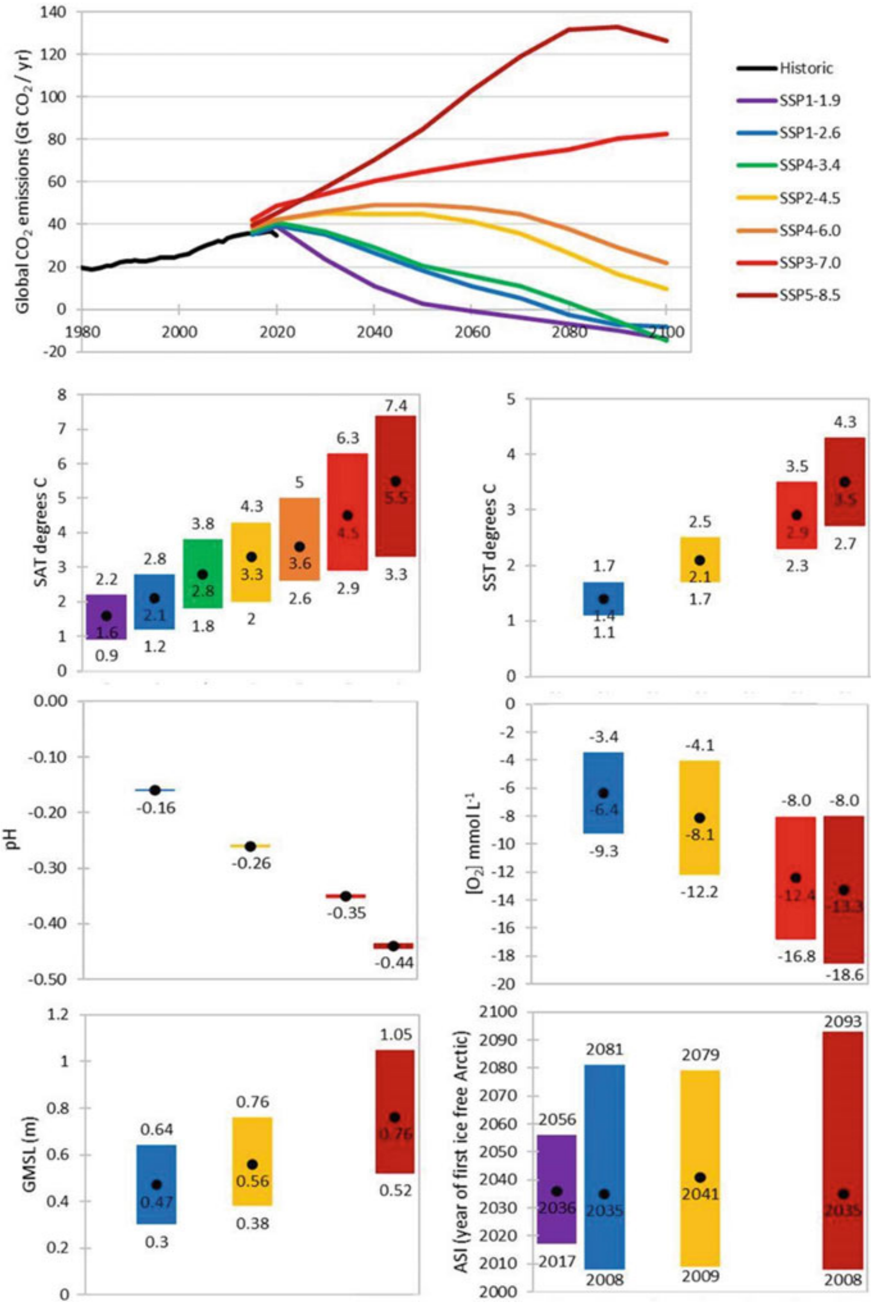
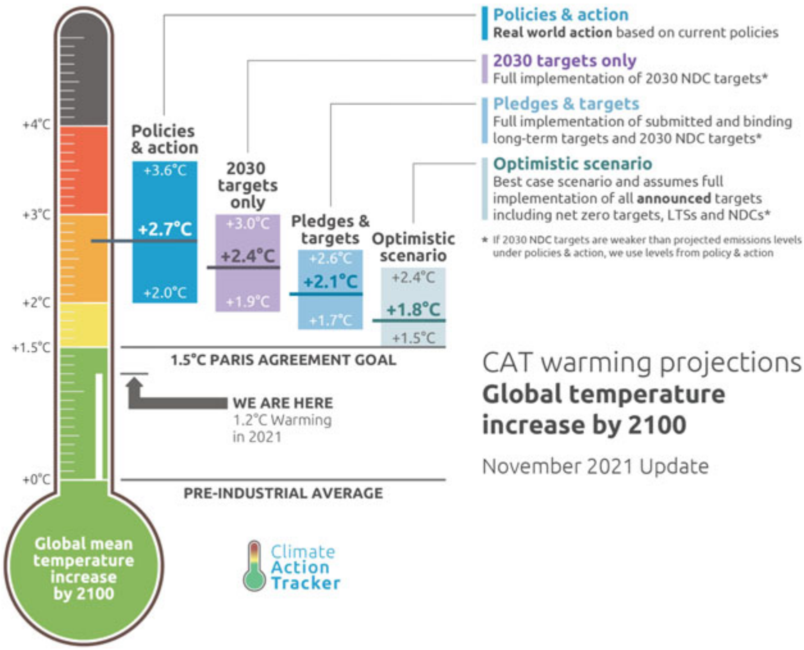


Fig. 1.1 Global CO_2 emissions, change in surface air temperature (SAT), sea surface temperature (SST), surface ocean pH, surface ocean oxygen concentration ([O_2]), global mean sea level (GMSL) rise and year of first Arctic sea ice (ASI) <1 million km^2 under the different Shared Socio-economic Pathway (SSP) and radiative forcing scenarios. See Table 1.1 for details

Is the World on Track for Meeting the Paris Agreement After the Latest UNFCCC COP26?

An independent scientific analysis project "Climate Action Tracker" (CAT) was set up in 2009 to track government climate action and measure it against the Paris Agreement https://climateactiontracker.org/. The project is a collaboration between Climate Analytics and the NewClimate Institute. They provide a suite of information, data analysis and infographics about the state of NDCs and what this means for realising the target of 1.5 °C warming. A key infographic "the CAT thermometer" is shown here. It was updated after COP26 and shows that there is still a gap between all policy pledges and targets and the 1.5° target. In other analysis, CAT shows that current pledges and policies for 2030 are 19–23 $GtCO_2e$ (billions of tonnes of global annual CO_2 equivalent emissions) higher than where they need to be in order to achieve a consistent 1.5° by 2100.



Credit Climate action tracker and the climate analytics/NewClimate Institute team

What Can Be Done to Stay (Get Back) on Track?

To address the cause of climate change, reductions in greenhouse gas emissions are needed in all sectors and systems, including energy; urban and other settlements; transport; buildings; industry; agriculture, forestry and other land uses and food systems. At the same time, actions taken to reduce emissions must be equitable, ensuring vulnerable communities can overcome the challenges associated with the impacts from climate change and the practicalities of reducing emissions. New policies will need to be developed with the aim of reducing emissions. At the same time, policies that currently encourage emissions, either directly or indirectly, will need to be rethought. Each country will need to develop its own nationally relevant approach to reduce emissions, which will feed into and affect international emissions reduction efforts.

As countries approach the task of developing a suite of actions to reduce their emissions, they can consider the protection and restoration of nature as part of their nationally determined climate plans. Some of these nature-based solutions to climate change can come from the ocean, as outlined in this section. It is important to remember however that not all ocean ecosystems are suitable for climate policies. The key to solving the climate crisis is emission reductions. Nature-based solutions must be actionable and lead to removal of carbon dioxide out of the carbon cycle. For example, protecting corals, fish and whales all contribute to a healthy ocean, are important to biodiversity, and help buffer against the impacts of climate change, but they are not currently actionable within climate context and in the case of corals will not lead to carbon removal.

Acknowledgements Thank you to all the authors of this section on climate change and the ocean for their input and review: Stacy Baez, Natalie Barefoot, Angela Martin and Heidi Pearson.

Further Reading

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The Carbon Action Tracker: https://climateactiontracker.org/

UNFCCC processes and meetings explained: https://unfccc.int/process-and-meetings

Dr. Helen S. Findlay I am a biological oceanographer actively researching the impacts of ocean acidification and warming on marine ecosystems. This research journey began while learning about the marine carbonate system and the potential of ocean acidification during my M.Sc. Oceanography degree in 2006. That was quite early in the concept of ocean acidification (OA), and we have come a long way since. I have always had a love of the ocean, and as my career took off, I realised I preferred the biogeochemical aspects of research more than the biology—finding out how the environment is changing then asking how it might impact the critters that live in it! So this is the research life I have pursued. I have always had a draw to the polar regions, probably from reading about famous polar expeditions as a child. As a result, I have spent a large portion of my research focussed on the Arctic. In the past 5 years, I have increasingly been engaged in science outreach, including attending and presenting at UNFCCC COP25 and COP26, as well as providing evidence and policy briefs for a number of governments and organisations internationally.

Chapter 2
Warming, Acidification and Deoxygenation of the Ocean

Helen S. Findlay

Introduction

The ocean plays an essential role in regulating Earth's climate. The ocean provides many services, but two crucial ones are its ability to take up heat and carbon dioxide (CO_2) from the atmosphere and cycle both around the world in its vast currents, as well as store them away long term. The ocean is changing rapidly and often unnoticed by the general public. However, as the effects of climate change become more prevalent on the ocean, we will start to see a direct impact on human society. This chapter discusses three main climate change effects on the ocean: ocean warming, acidification, and loss of oxygen. Each section also discusses the most significant impacts to marine species and ecosystems and finishes by highlighting the consequences for people.

Ocean Warming

The ocean takes up heat from the atmosphere and carries it around the world on ocean currents. Without the ocean naturally taking up heat, the atmosphere would be significantly hotter than it presently is. In fact, the ocean has absorbed about 90% of the excess heat from the atmosphere just in the last century. However, this is now causing an observable impact on ocean temperature, ocean properties, and the organisms that live in the ocean. The surface ocean has warmed, on average, at rate of 0.11 °C per decade since the 1970s, which represents part of a longer trend of ocean warming since the mid-nineteenth century.

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Ocean warming has knock-on consequences for many other parts of the ocean system: Warming can alter the global water cycle, which has substantially changed sea surface salinity in some regions. The rate of sea level rise since the mid-nineteenth century has been larger than the average rate during the previous two millennia. Over the period 1901–2010, global mean sea level rose by 0.19 m, and sea level rise continues due to freshwater additions from melting of glaciers and ice sheets and as a result of ocean expansion due to continuous ocean warming. There has also been a rapid decrease in Arctic sea-ice extent in all seasons, resulting from melting from both warmer air and ocean temperatures.

Marine heatwaves, when ocean temperatures are extremely warm for an extended period of time, are also increasing in frequency and intensity. These events can have very dramatic effects on marine ecosystems, including causing coral bleaching, causing harmful algal blooms, loss of seagrass habitats, die-back of kelp forests, species range shifts and changes in community structure, as well as megafauna and seabird mortality. Ultimately, these effects result in negative impacts to humans, for example, loss of fishing, aquaculture, or tourism activities.

Models project continued warming across the globe, with an average sea surface temperature rise between 1.4 and 3.5 °C by year 2100 depending on which future scenario is used in the projections. These sort of temperature increases do not seem much, but they can have significant consequences for marine ecosystems. Especially, when you consider that a marine heatwave of just 1 or 2 °C above normal can cause large-scale devastation of marine habitats and ecosystems.

For many marine creatures, the surrounding water temperature dictates their physiological performance, controlling the rate of processes such as growth and reproduction, and ultimately controlling survival. These creatures, known as ectotherms, have a temperature (or thermal) tolerance range for each process, which defines the temperature at which the processes can occur and beyond which they cannot continue. Knowing what these thermal tolerance ranges are allows us to predict how organisms might respond to changes in temperature but also explains the observations we see in terms of large-scale impacts of temperature on marine organisms. There are three main large-scale impacts:

The first impact is related to the temperature-size rule, which describes the correlation between increasing temperature and decreasing body size. In general, we find larger organisms in the deep ocean and in the Polar Regions where temperatures are colder, and smaller counterparts in the tropics. As climate change causes oceans to warm, we would expect that some species may respond by becoming smaller. This has been found in laboratory experiments, where warming has led to less growth, and in turn, this results in adults being smaller at the age of reproduction relative to organisms grown under colder conditions. We have also seen this effect in the fossil record—smaller individuals tend to have continued through mass extinctions events compared to their larger counterparts.

The second impact is related to the ability of populations to adjust the timing of key life history events, such as development or reproduction, to track their optimal thermal range. As ocean temperature warms, we would expect some species to be able to respond by shifting the timing of, for example reproduction, to earlier in the year when temperatures may be cooler and equivalent to present-day temperature. This is now quite commonly observed on land, for example plants that flower earlier in the year than they have historically. The strength and direction of these shifts can differ between interacting populations, which potentially leads to a mismatch between food availability, prey and predators, and ultimately results in a restructuring of the ecosystem.

The third impact is the movement of species to new geographic locations in order to follow their optimum temperature range. We are already seeing trends in warm-water populations expanding their biogeographic range towards higher latitudes, whilst cold-water populations are showing range contractions. These range shifts vary considerably between populations in both magnitude and direction. Range shifts could result in spatial restructuring of marine communities and consequently changes in food chain interactions and energy transfer, as well as biogeochemical cycling. Although the response of species to ocean warming is complex, models project that there will be declines in the overall global biomass of marine organisms by the year 2100 under all emissions scenarios, with projections of biomass decreasing at low latitudes but increasing at high latitudes.

There is no doubt the oceans are warming, resulting in substantial changes in the physics, chemistry and biology of the ocean. The majority of studies, experimental, observational and modelling, suggest that this will continue as long as climate change continues and will result in substantial changes to marine communities and ecosystems.

Ocean Acidification

The ocean takes up carbon dioxide (CO_2) from the atmosphere. It is one of our planet's greatest natural carbon sinks. Once in the ocean, CO_2 can react with water and becomes part of the marine carbonate system; a complex breaking down and reforming of ions and minerals that, over geological time-scales and without human intervention, balances the oceans chemistry and locks carbon away for millennia. Since the industrial revolution, roughly 250 years ago, the ocean has absorbed over 560 billion tonnes of CO_2 from the atmosphere, which is about a quarter of the CO_2 that has been emitted from human activities. This addition of CO_2 has happened so rapidly (geologically-speaking) that the oceans natural buffer system has not been able to keep up. The ocean chemistry is changing, resulting in a decrease in ocean pH (the measure of acidity) and making waters potentially more corrosive to calcium carbonate minerals. It is these changes that we call ocean acidification.

The chemistry is clear. Scientists are monitoring the amount of CO_2 in the atmosphere and in the ocean, as well as other aspects of the marine carbonate system, including pH. On average, the surface ocean has become about 30% more acidic between pre-industrial times and year 2000, although the rate of ocean acidification depends on the location and other factors such as proximity to land, rivers, ice, and nutrients. Future projections show that ocean acidification will continue, with global average pH declining a further 0.06–0.34 units by the year 2100, depending on the future scenario. However, questions remain about how ocean acidification will impact marine organisms—does this change in pH and chemistry matter to ocean plants, animals, their habitats, and ecosystems? In short, the answer is yes. This rate of change is unprecedented in the last 300 million years, so most creatures that exist today have evolved in a relatively stable marine system.

Oysters. *Credit* Sean Gardner/Greenpeace

Organisms need to keep their internal pH relatively stable so that cells and proteins can function properly. Some organisms have systems in place that can buffer changes in pH, whilst other creatures follow their external environment much more closely. Marine creatures that build calcium carbonate shells and skeletons, such as oysters, mussels, clams, urchins, crabs, coral, to name just a few, are at greater risk from ocean acidification because the change in chemistry means these structures are more easily broken down, and they need to put more energy into making, fixing, and maintaining them. Scientists have already observed some negative impacts in the ocean today: Coccolithophores, which are important phytoplankton (microscopic plants) that produce calcium carbonate 'liths' (platelets), have been declining in the Southern Ocean over the past 20 years. Along the North American west coast, oyster hatcheries are already experiencing reduced hatching success as a result of more acidic waters coming into the areas where they collect water to use in their hatcheries. In the Polar regions, (the Southern and Arctic Oceans), where seawater is already periodically found to be more acidic and corrosive to calcium carbonate, pteropods, tiny free-swimming sea snails, are being found with their shells cracked and pitted. In Australia, on the Great Barrier Reef, corals have experienced a decline in calcification and growth since 1990. These changes are likely to be a result of combined increased sea surface temperature, ocean acidification, and local stressors.

There are also many impacts being found on other processes, in addition to the basic effect of changing pH on organism physiology. Some examples of these altered processes include: the ability to sense and detect predators or prey; the nutritional content and even the smell of shellfish; organisms' behaviour and biological production of important climate-regulating gases. All these impacts, including the physiological effects, can have knock-on consequences for nutrient cycling and food-web functioning.

Despite the overwhelming findings of negative impacts, scientists are also finding some "winners," as well as negligible impacts. Algae and phytoplankton, the ocean's plants, benefit from more CO_2 because they need it for photosynthesis. Scientists are also finding that if a stressed animal is given enough food, i.e. enough energy, it can overcome some of the issues, such as reduced calcification, that it would otherwise face. The experimental evidence of how ocean acidification might impact marine creatures is complex. However, at ecosystem level—the food-web, ecosystem function and services—we have high certainty that ocean acidification will cause significant changes.

By looking at past events through Earth's history where there have been levels of CO_2 in the atmosphere that compare with the levels seen today and projected for the near future, we can see that if CO_2 emissions are unmitigated this likely results in widespread extinctions. It takes tens of thousands of years for ocean chemistry change to be buffered, and even then ocean pH eventually stabilises at a lower level than present. Urgent and substantial reductions in CO_2 emissions on a global scale are the only way to reduce the impacts of ocean acidification.

Ocean Deoxygenation

Ocean deoxygenation refers to the decrease in oxygen concentration that is currently going on in our oceans and is projected to continue into the future. All animals, including marine animals, need oxygen to breathe. Fully marine animals take oxygen out of the water using gills or directly through their 'skin'. It is much more difficult to remove oxygen when it is dissolved in water than it is as a free gas in air, so most marine animals are adapted to surviving in water that is fully or near-fully, saturated with oxygen (>80% saturated). In other words, the water has so much oxygen in it that no more would dissolve in it if you kept trying to add it. If oxygen levels drop below this, then water essentially becomes toxic to marine animals as they are unable to extract enough oxygen from the water to breathe and survive.

The primary causes of deoxygenation are eutrophication (increased nutrient run-off from land and sewage pollution) and nitrogen deposition from the burning of fossil fuels, coupled with the widespread impacts from ocean warming. In coastal waters, enhanced nutrient input from rivers, mainly from agriculture and wastewater, stimulates phytoplankton blooms, which subsequently die, sink to the seafloor and degrade. As they degrade, oxygen is removed from the water by respiring bacteria. Since the mid-20th Century, there has been a world-wide increase in river export of nutrients, resulting in widespread coastal eutrophication and a dramatic increase in the number of reported sites of low oxygen conditions. Not only does the degradation of organic matter remove oxygen, but it can also increase the acidity of coastal waters, resulting in enhanced local acidification and may also enhance the release of methane (an even more potent greenhouse gas than CO_2) from the sea floor.

Warming impacts the oxygen concentration of the oceans because, in terms of simple physics, warmer waters hold less oxygen. We can observe this in the ocean today: less oxygenated waters are found in warmer tropical waters compared to colder polar waters. Ocean warming also impacts the structure of water masses, resulting in increased stratification (or layering of the water column), which in turn reduces circulation and therefore also reduces oxygen exchange between the atmosphere, the surface ocean and deeper ocean layers. In general, the surface ocean tends to be saturated with oxygen, whilst deeper layers tend to have lower oxygen levels as a result of remineralisation (conversion of oxygen to CO_2 through respiration and other biological processes). Many ocean basins feature an oxygen minimum zone (OMZ), where few animals can survive for any extended period of time. Over the past 50 years, oxygen levels have reduced by 2% (from 1960 to 2010), resulting in an expansion of OMZs.

Expanding OMZs will alter the structure and function of benthic (sea-bed) communities on continental margins and shallow seas by reducing suitable habitat, reducing biodiversity, reducing body size, impacting food-web structure and shifting carbon and nutrient cycling. For example, OMZs play a crucial role in the global nitrogen cycle. OMZs are regions of substantial nitrogen losses and are responsible for producing a large fraction of the oceanic nitrous oxide (N_2O) emissions to the atmosphere. Expanding OMZs may therefore enhance N_2O emissions to the atmosphere, which will further exacerbate warming. In terms of impacts on marine animals, eutrophication events have historically caused widespread mortality of benthic invertebrates and fish species. However, often the worst hit species are the larger more metabolically demanding animals such as pelagic (open ocean) sharks and fish. The most affected species in terms of global ocean deoxygenation are tuna (Yellowfin, Bigeye, Pacific Bluefin and Albacore) and billfish (Swordfish). Ocean warming has a two-fold impact on high metabolism species, as warming increases metabolic demand, but warming also reduces the amount of oxygen available to meet that demand.

Over the whole global ocean, models project a further loss of 3–4% of oxygen by the year 2100 (RCP8.5 scenario), with most of this loss concentrated in the upper 1000 m of the ocean, where species richness and abundance are greatest. Regionally, the intensity of oxygen loss will vary depending on local dynamics, ecological and biogeochemical processes. Models project that oxygen loss will be strongest at mid- and high-latitudes.

As with ocean acidification and warming, the ocean has a long memory, and warming-driven deoxygenation, especially, cannot easily be reversed. It is expected to take centuries to recover from the worst-case warming scenarios. Given that one of the major drivers for deoxygenation is climate change, any stabilisation of greenhouse gas emissions would prevent the worst scenarios from coming to fruition and would allow the ocean to recover to some degree. Eutrophication-driven deoxygenation in many ways is easier to control, with the introduction of improved land management practices, cleaning up rivers and increasing monitoring activities.

Societal Relevance

People most at risk from ocean-related climate change are those who live close to the ocean or depend directly on their resources for their livelihoods. Climate change can result in direct impacts such as causing infrastructure damage, losing habitability and changing air quality. More indirect impacts include increased incidence of injuries, infectious diseases (like Covid), heat stress and mental health and wellness challenges, compromised food and water security and degradation of ecosystem services. Finally, there are the economic impacts due to reduced production, conflict, and widespread human migration.

The number of people living in low-lying coastal regions (defined as land <10 m above sea level) is set to increase to more than one billion by the year 2050. These communities will be specifically exposed to ocean warming (including heat waves), ocean acidification and deoxygenation, as well as resultant impacts of enhanced coastal erosion, increased wind, wave height and storm intensity. These conditions increase the risk to their livelihoods, including impacts on fisheries, tourism and trade, but also include loss of life, damaged assets and disruption of basic services.

Shellfish collected by women in Mar Lodj fishing village, Senegal. *Credit* Clément Tardif/Greenpeace

What Can You Do?

- Visit the seaside and appreciate its health-giving benefits (see Chap. 28 on Ocean and Human Health).
- Educate yourself and those around you, when possible, about our beautiful planet and its plight.
- Be mindful of being as 'green' as is in your power to be! Reducing emissions is the number one way we can limit the impacts of climate change on the oceans. It is everyone's responsibility to do their bit. From how you run your home, personal travel, where you buy your food, clothes and other goods, what you eat and where you invest your money. Industries must change their practises, and governments must fund and support green growth economies, renewable policies and set legislation.
- Finally, if it is possible for you to do so, go out and vote for those political parties that support action on climate change.

Further Reading

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Chapter 3
Blue Carbon

Stacy K. Baez

The Ocean, Carbon, and Climate

The ocean has always been integral to our climate. As scientists, we have long understood that the exchange of heat, moisture, and carbon between the ocean and atmosphere helps shape our climate. But in the last few decades we have come to understand the critical role of carbon in this system. Through the burning of fossil fuels and other human activities, the amount of carbon dioxide–a heat trapping gas important to many processes on earth–has risen by almost 50% since the start of the industrial revolution. While carbon dioxide is an essential component in our environment, the increasing level in the atmosphere is warming our planet and fundamentally changing our climate.

The ocean itself has absorbed almost 25% of this human-produced carbon dioxide, leading to changes in its chemistry, which impact marine life and weaken marine ecosystems. Although the ocean has been negatively affected by rising carbon dioxide levels, it is more than just a victim. Several ocean and coastal habitats are natural carbon sinks, meaning they can remove carbon out of the environment and lock it away by storing it in soils for long periods of time. Marine ecosystems like mangroves, seagrass, and saltmarsh that remove and store–or "sequester"–carbon are commonly referred to as blue carbon ecosystems. Protecting and restoring these special places through climate policies can be an important path forward in the fight against climate change.

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What is Blue Carbon?

Blue carbon refers to the carbon that is captured and held in ocean or coastal environments, hence the term blue. When we typically think of natural environments that capture and hold significant amounts of carbon, forests are forefront in our minds. But the ocean itself is actually the world's largest carbon reservoir with vast amounts of carbon trapped in the deep ocean. While all life in the ocean, and indeed the planet, has carbon, not all of it falls under the blue carbon umbrella.

All forms of ocean life contain carbon and some of this carbon eventually sinks to the deep ocean where it is locked away. As fish, whales, and other marine life die and poop, carbon moves down where it can be sequestered. But the amount of carbon that makes it to deep waters from marine life can be variable and difficult to measure. The carbon can also be locked away in the seabed outside of a country's jurisdiction making it difficult to manage. So the term blue carbon is used specifically to describe the marine ecosystems that remove carbon from the global carbon cycle on a scale to influence climate, and importantly, the carbon sequestered can be measured and managed.

Currently, there are three blue carbon ecosystems, known collectively as coastal wetlands: mangroves, seagrass, and saltmarsh. These may be familiar ecosystems to many of us because they are close to coastal communities and possibly near the beaches, deltas, and bays we may visit. Mangrove trees form forests that fringe coastlines in the tropics forming a belt around the planet. Saltmarshes are found in coastal areas across sub-tropical and temperate regions. Seagrasses, a group of marine flowering plants that contains over 60 species, can be found in shallow coastal waters worldwide—everywhere, in fact, except for Antarctica.

Similar to forests on land, these coastal wetlands absorb carbon dioxide and use this carbon to grow, producing roots, stems, and leaves. Over time, vegetation and roots from these plants and trees die, and decompose, and the carbon that was previously held in living material becomes incorporated into the soil below. One key issue to keep in mind, is that while plants take in the gas carbon dioxide, which is composed of both carbon and oxygen, it is only the molecules of carbon that is sequestered into the ground. Helpfully, the oxygen goes back to the atmosphere. While this is the same process that occurs in forests on land, blue carbon habitats are much more efficient at trapping and storing this carbon in soils than their terrestrial counterparts. For example, the soils in mangrove forests can store three to five times more carbon per square mile than other forests. So, what makes these blue carbon habitats so good at storing carbon? The secret lies in the ocean water.

Mangroves, seagrass, and saltmarsh are all found in areas that are either submerged or frequently flooded by tides. This wet setting is low in oxygen creating an environment that slows the decay of plant and other organic material. As result, these blue carbon ecosystems accumulate rich organic soils over time that if left undisturbed, can lock carbon away for decades or even millennia. In fact, over 90% of the carbon stored in these ecosystems are found in soils with some of this carbon being thousands of years of old.

Despite occupying less than 2% of the ocean, these three blue carbon ecosystems play an outsized role in carbon sequestration. For example, it is estimated that seagrass bury more than 10% of all organic carbon sequestered in the ocean. In addition, coastal wetlands can also sequester carbon coming from outside the ecosystem: the roots of the mangrove forests might trap leaves and debris from other plants on land; organic material that washes down into a saltmarsh can get trapped and buried there; and organic waste from marine life can fall into a seagrass meadow and be sequestered.

There is a growing body of research around blue carbon ecosystems and new science suggests that some other marine ecosystems, like kelp, might also offer carbon capture and storage potential. Kelp are giant algae, not plants, and lack the root system necessary to trap carbon in sediments. Although kelp absorb carbon dioxide, the carbon burial process into sediments is a bit different. As kelp die, it can be swept off into deep waters where eventually some of it reaches the seafloor and is buried. This form of carbon sequestration is more difficult to manage since the amount of carbon being sequestered is influenced by numerous factors, such as ocean currents. Nonetheless, in certain specific situations kelp may be an emerging blue carbon ecosystem and warrants more research.

Salt Marsh on Wadden Sea. *Credit* Bernhard Nimtsch/Greenpeace

More Than Just Carbon

The value of blue carbon ecosystems goes beyond the amount of carbon removed from the environment. These ecosystems provide numerous climate adaptation benefits that can help communities adapt to a changing climate. Scientists predict that as the atmosphere and oceans continue to grow warmer, the intensity and frequency of storms will increase—a trend we are already experiencing on a global scale. As discussed in Chap. 19, mangroves, seagrass and saltmarsh provide a front-line defense against storms. They stabilize shorelines as their roots hold on to sediments and soils that might otherwise be disturbed by winds and floods. These ecosystems also help reduce wave impacts, buffering coastal communities from the full effect of storm-induced waves. Mangroves alone help reduce property damage from floods by more than $US 65 billion per year.

These ecosystems also provide services that help people thrive. Many fish, birds, turtles, and marine mammals depend on these three ecosystems for nursery areas, shelter and feeding grounds. As such, coastal wetlands contain a myriad of species that support food security, recreational activities, and tourism. Seagrasses alone have a significant impact on fisheries. It is estimated that one fifth of the world's most widely caught fish species depend on seagrass for habitat. Think of fish like cod or pollock, species that are familiar to many of us, and if you eat fish, may be a regular on your dinner plate. The diversity of life found in these blue carbon ecosystems provide opportunity for tourism the world over. Those of us who kayak, canoe, snorkel or dive can attest to the joy of these experiences in various coastal wetlands.

We are also understanding the importance of these places to the cultural well-being of societies. The value of a mangrove forest for recreation and solitude is not readily measured. Some Indigenous cultures depend on coastal wetlands and keeping these systems healthy and intact goes hand in hand with the well-being of these societies in the face of the enduring climate crisis.

Losing Our Blue Carbon Ecosystems Means Trouble

Unfortunately, coastal wetlands are among the most threatened ecosystems on the planet. These ecosystems–commonly associated with places where rivers meet the ocean like deltas and estuaries–have been home to human societies for hundreds of years. Centuries of collective impacts like clearing mangroves and salt marshes for development, pollution, and changes to water quality and water flows are now pushing these systems to the edge. Driven by human actions, these ecosystems now cover only half of their original extent.

The loss and degradation of blue carbon ecosystems have significant impacts to our global society and to nature. When coastal wetlands are destroyed or degraded, not only is less carbon dioxide actively removed from the environment, but the carbon that was previously stored in soils is released back into the atmosphere as carbon dioxide. Losing a single mangrove forest for example can release hundreds of years' worth of carbon in a few decades. The loss of coastal wetlands creates a negative system that further exacerbates climate change.

Beyond the implications for carbon sequestration, the loss of coastal wetlands also means the loss of the many critical services they provide. Without the shoreline stabilization, flood protection, and water filtration that act as a natural defense system, coastal communities are left more vulnerable to the impacts of severe storms. The economic impacts from coastal wetland loss to communities can also be quite significant, particularly in terms of fisheries and tourism. For example, the life cycles of many fish species require nursery in sheltered areas, often in blue carbon ecosystems. As mangroves, seagrasses, and saltmarshes become degraded or lost, there will simply be fewer fish, affecting food security and livelihoods for people who live both near and far from the coast.

Blue Carbon Ecosystems Can Be Protected Through Climate Policy

While scientists have long recognized the value of blue carbon ecosystems, policy makers have lagged, and are only recently taking notice. There is a growing call within the climate policy arena to protect natural systems that help reduce carbon and build resilience to climate change, often referred to as “nature-based solutions” to climate change. Since blue carbon ecosystems act as natural carbon sinks by absorbing and storing carbon in a consistent, measurable way that can be managed, they are key nature-based solutions and excellent candidates for climate policy.

Currently, mangroves, seagrass, and saltmarsh are the only marine ecosystems recognized by the United Nations global body on climate change for their value in carbon removal. This global body, known as the Intergovernmental Panel on Climate Change, also provides methods to measure the amount of carbon currently removed and stored by coastal wetlands. These measurements allow governments to balance the amount of carbon removed by coastal wetlands and other nature-based solutions versus the amount that enters the atmosphere from human activities. If the balance sheet is done correctly, they can create a system where no net carbon dioxide would enter the atmosphere or, essentially, become carbon neutral. In order to achieve zero net emissions, nations will need to take decisive action to reduce emissions alongside protecting and restoring natural systems.

Across the world, a growing number of countries are interested in protecting blue carbon ecosystems as part of their climate response policy. One key policy framework that many countries are using to meet climate objectives is the Paris Agreement. This global treaty seeks to keep the planet’s warming below 2 °C (degrees Celsius) or 3.6 °F (degrees Fahrenheit)—but preferably no more than 1.5 °C (2.7 °F)—above pre-industrial levels. Countries will put forward action plans, known as nationally determined contributions, every five years to meet this collective goal. The nationally determined contributions put forward are expected to become more ambitious over time and ambition has increased based on commitments announced at the recent UNFCCC COP26 meeting in Glasgow, 2021. The restoration and protection of blue carbon ecosystems can be a part of these plans; developing countries can even receive international financial support to develop and implement some of these climate change actions.

Island nations and developing states are currently leading the charge in protecting blue carbon as part of their commitments to meet the goals of the Paris Agreement. Costa Rica, a champion for the environment, has inventoried its coastal wetlands and made a commitment to protect and restore these areas while aiming to stop or revert loss by 2030. The Caribbean country of Belize is also taking bold steps by committing to protect 12,000 hectares of mangroves by 2030 and to develop a national seagrass plan. While Seychelles has committed to fully protecting mangroves and seagrass by 2030. These commitments are expected to become more ambitious every five years, creating a system by which less carbon dioxide enters the atmosphere over time.

Creating policies to protect and restore these ecosystems on a country level are much-needed large-scale actions, but smaller efforts can also have meaningful impact. In the United States, state-level blue carbon protections can be site specific, applying coastal management approaches to conservation through regional or local policies. For example, protecting and restoring saltmarsh ecosystems at various sites can help capture and store carbon, mitigating the underlying cause of climate change, while also providing flood protection benefits and allowing communities to better adapt to storms and other weather events.

Seagrass and corals on the Saya de Malha Bank in the Indian Ocean. *Credit* Tommy Trenchard/Greenpeace

What is Next for Blue Carbon?

The field of blue carbon ecosystems is fascinating and dynamic. There are many aspects on the horizon that can help shape both ocean conservation efforts and move the needle on climate change. Here are just a few areas where scientists, policy makers, and economists are actively engaged.

Research: There is a world of interesting and exciting research that rests within the blue carbon space. Researchers are observing, mapping, and monitoring these systems. They are working to better understand the carbon sequestration rates for specific areas, the potential carbon dioxide and other greenhouse gas emissions from habitat destruction and degradation, and ecosystem and climate interactions. There is a growing body of work around other potential blue carbon ecosystems like macroalgae such as kelp.

Policy: Countries around the world are recognizing the valuable role that blue carbon ecosystems can play in meeting climate objectives. A concerted effort to mainstream good coastal management practices by advancing effective policies can lead to a stronger climate response and benefit societies at the local level. By including blue carbon ecosystems in climate policies and in carbon accounting, as is done for forests, nations can improve their management of these systems to protect carbon stores and the myriad of climate benefits they provide.

Financing: While not specifically discussed in this chapter, blue carbon ecosystems can form part of the wider "blue economy" (see Chap. 22). Like forests, the carbon capture of these systems may be eligible for carbon markets. Protection and restoration commitments can be financed through global climate-related funds, and new innovative approaches such as reducing a country's debt to secure conservation actions can also be applied. Blue carbon offers a new and interesting approach to finance the conservation of critical ecosystems.

How Can You Help?

Blue carbon offers a path forward to help reduce carbon dioxide and build resilience to climate change. Through collective actions we can further protect and restore these critical ecosystems and everyday citizens can also be a part of this movement. For example, talking to local government about how blue carbon ecosystems are being protected and whether they are being considered for incorporation into carbon inventories can be a first step. Even non-policy actions such as considering sustainable seafood choices can be impactful. Particularly in the case of mangroves where destructive shrimp farming can be a leading cause of mangrove loss. While traveling consider eco-friendly coastal recreational activities such as kayaking. This can be a great way to experience the magic of these habitats while supporting local economies. It is crucial that we stop the further decline of blue carbon ecosystems.

Only through decisive collective actions can we protect and restore these critical ecosystems.Seagrass and corals on the Saya de Malha Bank in the Indian Ocean. Credit: Tommy Trenchard/Greenpeace

Further Reading

Curious about greenhouse gas inventories? Check out this summary: https://www.wri.org/insights/greenhouse-gas-emissions-natural-working-lands

Want to learn more about blue carbon in general? Check out the Blue Carbon Initiative's website: https://www.thebluecarboninitiative.org/

Want a summary of blue carbon? See this analysis piece: https://www.pewtrusts.org/en/research-and-analysis/articles/2021/09/24/blue-carbon-a-natural-ally-in-the-fight-against-climate-change

Dr. Stacy K. Baez I am from Trinidad and Tobago, a twin island nation in the Caribbean, where I grew up about an hour's drive from the ocean. The ocean plays a considerable role in island communities by supporting livelihoods, food security and recreation. But when I came to the United States to study biology at Morgan State University in Baltimore, I gained a deeper understanding of how much we need the ocean. I learned about the ocean's critical role in shaping our climate and the ways in which human activities affect ocean health. I went on to pursue a doctorate in oceanography at Old Dominion University in Virginia where I studied the survivorship of juvenile spotted seatrout on seagrass beds in Chesapeake Bay. Seagrasses are among my favorite marine ecosystems. They serve as habitat for many marine species and can play a role in reducing the impacts of climate change. Through my studies, I realized that human well-being rests in the health of our global ocean and we need to take steps to safeguard it. I have since worked at the US National Science Foundation in the Ocean Sciences Division as a Knauss Marine Policy Fellow. More recently I have moved to the non-profit conservation arena where I have worked to protect sharks and improve shark conservation measures at several international fisheries management organizations. These days, however, I am working to protect and restore critical blue carbon ecosystems, namely mangroves, saltmarsh and seagrass through climate policies.

Chapter 4
Fishes and Carbon

Angela Martin

Introduction

The ocean is a carbon sink, meaning it removes more carbon from the atmosphere than it releases. Carbon that reaches very deep water or ocean sediments can stay out of the atmosphere for hundreds of years. Most carbon is absorbed and stored in the ocean through physical processes, but bacteria and plants, which convert dissolved carbon dioxide into organic carbon, can also keep carbon in the ocean (see Chap. 3 on Blue Carbon). Fishes (and other animals) also play a part in promoting uptake of carbon by bacteria and plants, and in moving carbon.

The Forms of Carbon

Inorganic Carbon

Inorganic carbon is carbon that is not in compounds formed biologically by bacteria or plants. For example, carbon dioxide is a form of inorganic carbon. As we know, carbon dioxide is a greenhouse gas, which means that when it is in the atmosphere, it contributes to climate change. When carbon dioxide is absorbed into the ocean it is dissolved, which means it is present as liquid, where it forms carbonic acid and can react to form other compounds as it mixes into the seawater. Due to continued release of greenhouse gases from human activity, there has been an increase in carbon dioxide in the atmosphere and, subsequently, an increase in dissolved carbon dioxide being absorbed from the atmosphere into the ocean. The increase in dissolved

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carbon dioxide has affected the chemistry of seawater (see Chap. 2 on Warming, Acidification and Deoxygenation of the Ocean).

Organic Carbon

Dissolved carbon dioxide provides a building block for marine bacteria and plants to form organic carbon. Bacteria and plants use sunlight to biologically convert dissolved carbon into organic carbon, through a process called photosynthesis. Organic carbon in plants and bacteria is bound with other elements, such as hydrogen and oxygen, forming organic compounds. Some organic carbon is stored in the bacteria or plant where it forms the tissues, can be used for growth and maintenance, or can be converted back to dissolved carbon dioxide to provide energy, such as for movement.

How Do Fishes Affect Carbon?

As with all animals, the life processes of fishes are carbon-driven.

Food!

Fishes eat carbon-based food—and become carbon-based food. At the bottom of the food web are plants, which remove carbon dioxide from the water and convert it into organic carbon. When fishes eat plants directly or eat other animals that have eaten plants (including other fishes), the organic carbon can be accumulated in the fishes' own bodies or released again to the water. Some of the carbon fishes eat is used to fuel movement and other processes in fish's bodies, which results in the carbon being released. This released carbon can take several different forms. For instance, when fishes breathe, they release carbon as dissolved carbon dioxide; and fishes' poop can contain both organic carbon from their food as well as inorganic carbon, as most marine fishes (those classified as teleosts) excrete inorganic carbon to help get rid of unwanted compounds in seawater, which they drink. Carbon excreted by fishes may be carried away by water movement, sink to the sediment, be eaten by other animals, react with other chemicals to form different compounds, or get taken up again by plants or bacteria. In fishes' bodies, carbon is used for maintenance, keeping the fishes healthy, and for growth. Some carbon is used when fishes produce offspring or gametes. Eventually, the carbon in the fishes' bodies sinks when they die, or is passed to the bacteria, predators or scavengers that eat them.

Atlantic Cod, Norway. *Credit* Joachim S. Mueller/Greenpeace

Behaviour

Fishes' behaviour affects carbon in the environment. Firstly, because fish move, they transport the carbon they have eaten with them, wherever they go. Both the carbon they continue to release in excretions and breath, and the carbon stored in their bodies, is transported from one place to another. The carbon in fishes' bodies and poop is available to predators and scavengers in their new location. Because some fishes move vertically in the ocean, from shallow to deep water, they can transfer carbon across important physical boundaries. For example, small fishes that live in the open ocean and migrate vertically can move carbon downward by eating at night in shallower water, and then resting during the day in the depths, sometimes called the twilight zone. In the twilight zone, these fishes release carbon by breathing, pooping, dying, or being eaten by predators. Deep-sea fish communities that do not migrate, but eat animals that do, can also be important for storing carbon from the surface in the deep ocean, far from the atmosphere.

Secondly, the behaviour of fishes within a habitat can affect the carbon in the environment, including in the plants, in other animals, and in the sediments. Species that play an important part in the function or conversion of a habitat are known as ecosystem engineers. Some examples of how fishes move or otherwise affect carbon in their habitats include:

1. Predatory fish control populations of their prey, and their prey's prey, down to the primary food source. When too many predators are removed from an ecosystem, the knock-on effects in the food web can be seen all the way down to the base of the food chain and can even result in change of habitat. For example, cod fishes could be important for controlling sea urchin populations in kelp forests along the coast of Norway. Kelp is a type of algae that not only forms underwater forests that are important for wildlife, including other types of algae, crabs, worms, sea stars, snails, and fishes, but can also be important for carbon sequestration. When too many cod were removed by fishing, the number of sea urchins increased and grazed so many kelp plants that some areas of kelp forest disappeared, leaving only bare rock. Predators also affect the behaviour of their prey. For example, when predatory sharks are present in an ecosystem, plant-eaters such as turtles, dugongs, and fishes often change their feeding behaviour, including through eating fewer plant roots, or eating close to shelter, as feeding in the open increases the risk of predation. This affects where and how much seagrass, algae, or other plants these animals graze. In some areas, such as blue carbon habitats (see Chap. 3 on Blue Carbon), this predator effect helps protect carbon stored in sediments and plants, as well as the processes that lead to carbon storage.
2. Fishes often use habitats in ways that change the habitat features. This can be small-scale or large-scale, and includes biological, chemical, or physical changes. For example, blacksmith fishes eat zooplankton during the day and every night they deposit organic carbon in their poop into the crevices on rocky reefs which they use for shelter overnight. This carbon is then available for the animals and bacteria that live on the seafloor. Nest-building fishes, such as wrasses, collect pieces of algae from around their habitat and build nests on the sea floor during the breeding season. Some tilefishes burrow over a metre into clay or mud to hide from predators, creating large burrows that can erode sediments, change the surface features of the sea floor, and provide shelter for other animals.
3. Fishes can also affect carbon uptake and storage in their habitats by providing nutrients in their bodies and waste. The Sargasso Sea is an area of sea very far from land. It is unique in that it has no land boundaries. Instead, the boundaries are formed by four currents that circulate the area. It is named after the algae Sargassum, which forms the main habitat. The water is low in nutrients needed by plants, yet there are some hotspots in the sea where the Sargassum thrives. In these areas, fishes like jacks and filefishes are important for the plants health and uptake of carbon, as they excrete nutrients that are essential for photosynthesis to happen. Another example is salmon returning from the ocean to spawn in rivers. Salmon bring both carbon and nutrients from the ocean, moving carbon out of the ocean and into terrestrial food webs and providing nutrients that are used by trees to photosynthesise and grow.

School of Fish, Raja Ampat, West Papua. *Credit* Paul Hilton/Greenpeace

Managing Fishes for Carbon

There are several challenges to managing fishes for their carbon benefits and contribution to ecosystem function. Firstly, there is not enough detail to be able to manage fishes for their part in promoting uptake and storage of carbon. However, further research could enable existing management of carbon in marine ecosystems to consider how the functions of fishes might be important for the carbon, and how fishes are affected by the management actions in place. Secondly, there are some areas that fishes are known to be important for carbon function but are not easy to manage. The deep twilight zone habitats that fishes move carbon into generally exist very far from coasts, outside of areas controlled by a single nation. In those parts of the ocean, no one country can include them in national policy; only through an international agreement could their carbon sink function be protected.

What Happens to the Carbon?

The important thing to know is, what happens to the carbon affected by fishes? As we have seen, it can be released to the water column (and back to the atmosphere), converted from inorganic to organic carbon by photosynthesis, moved upward or downward in the water column (including to sediments), or stored over a short-term or long-term. If you want to manage an ecosystem to keep carbon in the ocean and out of the atmosphere, and the most important outcomes to maintain are the conversion of dissolved carbon dioxide to organic carbon, the downward movement of carbon, including into the sediment, and the long-term storage of carbon.

Why Is It Important to Understand How Ecosystems Work?

How an ecosystem works or functions is a result of the physical, chemical, and biological parts of the ecosystem. Ecosystem functions, particularly those that benefit humans, are used in decision making and informing management, for example, by the United Nations in policies addressing climate change, conserving biodiversity, and achieving the Sustainable Development Goals (also known as Agenda 2030).

Climate Change

There is a United Nations Framework Convention on Climate Change (UNFCCC) that aims to address the issue of climate change. Governments that sign on to UNFCCC Agreements, such as the Paris Agreement, report the actions that they will take to (1) reduce their greenhouse gas emissions (including carbon dioxide) and (2) reduce the impact of climate change in their countries. As discussed in Chap. 3 on blue carbon, coastal ecosystems such as mangroves, seagrasses, and salt marshes can store a lot of carbon in soils trapped by plant roots. Many coastal and island governments have therefore included protecting or restoring coastal ecosystems in their climate action plans. But, by focusing just on the plants, we miss the whole ecosystem perspective. We need to consider how the entire ecosystem functions to effectively preserve the carbon in the soil or the deeper water.

Biodiversity

The United Nations also has a convention on the conservation of biodiversity. Each country that has signed up to this convention submits a national biodiversity strategy and action plan, which outlines their intentions for conserving biodiversity in their country. The Norwegian action plan states: "*Through conservation and sustainable use, we will seek to maintain the supply of ecosystem goods and services for the future*". Understanding ecosystems and their complexity is critical to ensure conservation actions are effective and that decisions on sustainable use do not disrupt their function.

Agenda 2030

Agenda 2030, or the United Nations Sustainable Development Goals, include aims like ensuring a healthy ocean and terrestrial ecosystems, using resources sustainably, achieving food security, gender equality, and ending poverty and hunger. These goals are underpinned by nature, which provides us with the resources, climate, support, cultural, and spiritual well-being we need. Thus, we must understand how an ecosystem functions to be sure that decisions made on how to manage it are effective and do not cause damage.

Summary

In order to manage ocean resources in a sustainable way and maintain an ecosystem's functions, including for carbon, the functions of fishes cannot be ignored. To understand the overall carbon function of a fish or community of fishes in an ecosystem, research into the carbon functions of the life processes, behaviour, food-web interactions, and nutrient provision is necessary. Furthermore, the outcomes of the carbon affected by fishes need to be understood. In addition, approaches to policies or management may need to be adapted to be able to include the role of fishes in protecting or maintaining the carbon functions of ecosystems. For example, where the final outcome for carbon is hard to measure, or the ecosystem or fish population spans more than one national jurisdiction or is in international waters, policies will need to be adapted to reflect this. As such, while research continues, we are very far from knowing enough to reliably inform decisions on climate change, biodiversity, and the UN Sustainable Development Goals (SDGs).

Suggestions of What People Can Do

While the ocean is a carbon sink and can help us to fight climate change, the only way to stop climate change altogether is to stop releasing the greenhouse gases that cause it. Some ways we can help to make this happen are:

1. If it is possible and appropriate where you live, you can write to your political representative, and ask for them to support the government to reduce emissions. We can also share our support for emissions reductions on public platforms like social media, or by taking part in organised actions and joining movements, such as Fridays for Future.

2. We can each reduce our personal footprint by not travelling by aeroplane, and as much as possible, choosing modes of transport that do not run on fossil fuels; buying fewer goods that need to be shipped large distances or flown by air; and having more plant-based foods in our diets.
3. Having a good awareness of nature and its importance, making observations about how and why it is changing, and sharing our knowledge with others.

In addition to stopping greenhouse gas emissions, governments must also work to restore and protect the very systems that are important for the ocean's carbon cycle. This includes fish populations. If you eat seafood, you can help by being mindful of the type of seafood you eat, making sure that it is caught sustainably. More details on the actions we can each take to help restore the world's fish populations are covered in Chaps. 6, 9, and 10.

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Angela Martin I am from a coastal village in Essex, England. From a young age, I developed a love for animals and nature. The sea and its hidden world of strange creatures were a huge source of curiosity for me, which led me to study marine biology. I completed a bachelor's degree at University of Portsmouth, a master's degree at University of Essex, and am now working towards a PhD on coastal ecology. In between my studies, I have worked with ocean conservation organisations, government agencies that monitor pollution, and an office of the UN Convention on the Conservation of Migratory Species, which facilitated the conservation of dugongs and their seagrass habitats. Through all these experiences, I have seen, time and again, that the challenges facing the ocean are ultimately human, and so humans need to be central to the solutions we develop to conserve, restore, and enjoy nature. Being involved with Women4Oceans helps me to stay focused on supporting the diverse ocean community to thrive and continue their important work for the health of the ocean.

Chapter 5
Whales and Climate

Natalie Barefoot and Heidi Pearson

Introduction

"This day in y' afternoone wee saw multitudes of great whales, which now was grown ordinary and usuall to behold."—Journal of Richard Mather as he crossed the Atlantic Ocean in 1635.

There was a time when the oceans teemed with whales. Humans interacted with whales with both fear and reverence, viewing them as relatives, sustenance, and messengers. When humans discovered that their blubber (and in the case of sperm whales, spermaceti) could be turned into fuel for lamps and lubricants for machines, large-scale commercial whaling began. Indeed, whales fueled the industrial revolution. Whaling has driven at least one population to extinction and many species to the brink of extinction. Fortunately, the global community agreed, with some exceptions, to a moratorium on commercial whaling in 1982 that took effect in 1986. Today, some populations of whales have recovered, but many are still at risk. Regardless, whale populations are nowhere near their original abundance with some populations reduced by an estimated 99% of their pre-whaling numbers.

Today, whales face bigger challenges than the harpoon, one of which is the ever-increasing threat of climate change.

However, while whales can be negatively impacted by climate change, they also provide a key opportunity to combat climate change by helping to trap carbon from the atmosphere. This concept of "whale carbon" is an exciting area of research that can aid in whale conservation in addition to combatting climate change.

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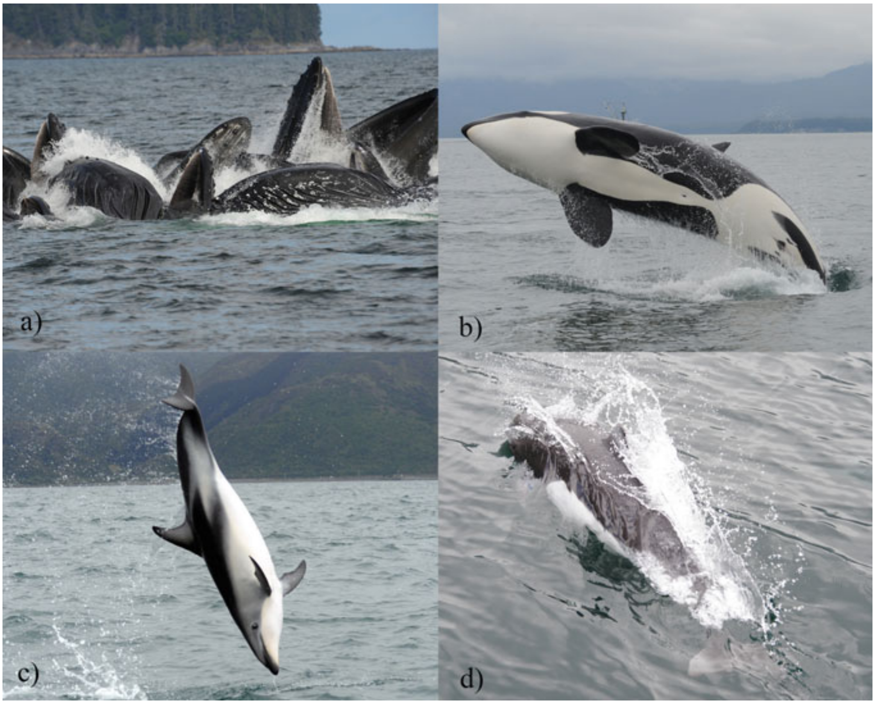


The term “whale” broadly refers to all cetaceans: **a** baleen whales, such as humpback whales, **b** toothed whales such as killer whales, **c** dusky dolphins, and **d** Dall’s porpoise. However, in this chapter, we primarily focus on the “great whales” which include baleen whales and the sperm whale (a toothed whale). These are the largest whale species, which were also historically targeted for whaling. Photos taken under NMFS permits #100818-01 (**a**) and 18529 (**b**), and DOC permit 37696-MAR (**c**)

How Climate Change Affects Whales

Our understanding of how climate change is affecting the oceans and its wildlife generally lags behind our understanding of climate effects in terrestrial ecosystems. The ocean’s size and complexity create an environment that makes collecting data difficult. In addition, climate change generates uneven impacts throughout the ocean, which absorbs approximately one-quarter of anthropogenic (human-produced) carbon dioxide. Thus, interactions between ocean processes and the climate vary greatly by area, making it hard to predict how weather, ocean circulation, and biological productivity are affected, and therefore, how wildlife is affected and may respond.

Despite this, we do understand that whales face both direct and indirect impacts from climate change. Climate change is affecting whales by altering their habitats and shifting the amounts and locations of their food sources. In response to these impacts, whales may respond outwardly through changes to their behavior, habitat use, migratory patterns, and diet, or inwardly through changes to their physiology. In extreme cases, cetaceans may fail to reproduce or adapt, leading to population declines or extinction. At the same time, climate change exacerbates the significant pressures that humans already have placed on whales' habitats including: ship strikes; entanglements with fishing gear; oil and gas exploration and drilling; mining; and noise, plastic, and chemical pollution.

It is important to remember that the climate has naturally changed throughout Earth's history, and whales have adapted to these changes through natural selection. However, the current pace of climate change is occurring more quickly than the rate at which evolution can occur. While many whales can and will adapt, others may not have the ability to do so. Below, we describe some of the direct and indirect ways climate change is affecting, or predicted to affect, whales.

Direct Effects

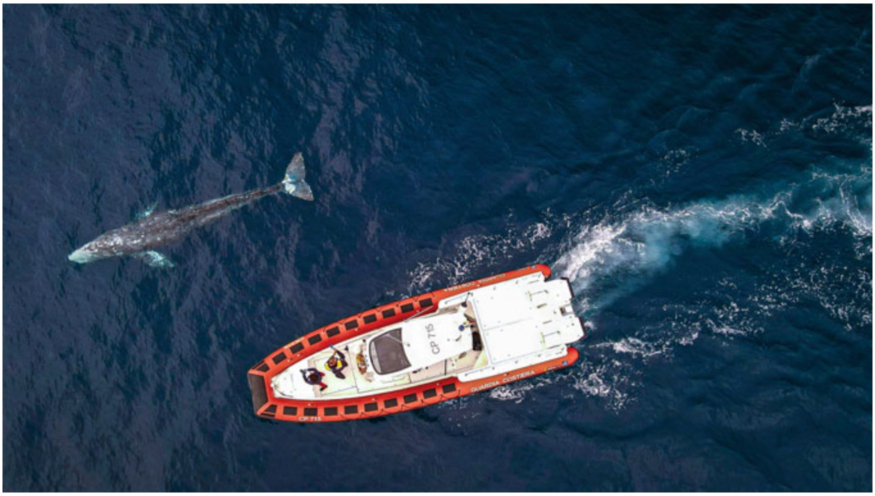
Climate change is causing an increase in water temperature, which may cause changes in whale ranging and migratory patterns.

Ranging patterns: Climate change is increasing the temperature of the ocean. As the ocean warms due to climate change, some whales are shifting their ranges. A range refers to all areas of the ocean where a whale is found throughout its lifetime. By looking at the temperatures within each species' optimal range, we can estimate how increasing water temperatures will affect and shift cetaceans' ranging patterns. According to scientists, 58% of cetaceans may increase their optimal ranges due to increased water temperatures and 40% may experience decreases in their optimal ranges. Although many cetacean species may experience increases in their optimal ranges, it does not mean that the habitat will also be optimal. Those cetaceans that experience a decrease in optimal range will either have to adapt to the new temperatures in their ranges or face either extinction or significant decreases in populations.

We can already see the effect of increasing temperatures in our ocean. In 2021, a gray whale nick-named "Wally" by biologists was sighted off the coasts of Europe and Africa. This sighting was highly unusual because Atlantic gray whale populations were deemed extinct in the 1700s due to whaling activities. Wally is believed to have traveled from the Pacific to the Atlantic by way of the Arctic. This path would typically be restricted by ice but is now possible because of declining sea ice due to climate change. While whales occasionally appear outside of their normal ranges and habitats—sometimes because they are exploring, other times because they may be unwell—shifts in ocean temperatures may open the door for more extreme cases of range shifts as shown by Wally.

Migratory patterns: Some whales, like humpback, gray, blue, and right whales, migrate. This means that they spend the warm summer months in higher latitudes. During those times, whales feed on food, like krill and herring that is abundant there. During the cool winter months, whales travel thousands of kilometers toward the equator to calving and breeding grounds where pregnant females will have their calves. Males and females also breed in these areas. These migrations take place over incredible distances. Gray whales, for example, log some of the greatest distances covering up to 22,500 km (14,000 miles) roundtrip.

Climate change will likely affect whale migration in various ways, both in the timing of migrations, and the route taken. With waters now warming and cooling at different times, changes in the timing of migrations have been documented. Sometimes, whales may not migrate at all. For example, a population of bowhead whales, which typically migrate south to the Bering Sea during the winter, remained in the colder waters of the Beaufort Sea and Amundsen Gulf during the 2018–2019 winter, an occurrence which had not been documented previously.



Wally the whale, seen here with researchers off the coast of Italy, is believed to be a gray whale from the Pacific Ocean who migrated to the Atlantic Ocean through the Arctic. Wally traveled over three months from Morocco to the Mediterranean Sea with scientists observing him off the coasts of Italy, France and Spain. Wally became thinner and weaker and was last sighted near the Balearic Islands on May 25, 2021. Wally is believed to have passed away due to lack of nourishment. © Tethys Research Institute and Guardia Costiera Italia

Indirect Effects

Climate change will indirectly affect whales in many ways including through changes to food webs and the exacerbation of other anthropogenic stressors.

Food webs: Climate change indirectly affects cetaceans by changing the abundance and location of their food sources. In response, cetaceans may switch to different food sources within their current range, find new feeding grounds with greater food availability, or starve. For example, temperature increases may affect krill populations by reducing hatching success as well as reducing ice cover and changing ocean fronts, which dictate the availability of krill. Blue whales in the southern hemisphere travel thousands of kilometers to Antarctica to feed on krill during the austral summer. This, combined with an increasing krill fishery in Antarctica may disrupt migratory patterns and timing as well as whales' abilities to birth calves. Since the timing of whale migration toward the poles corresponds with increased abundance of food at high latitudes, shifts in prey are likely to affect migratory patterns for other species as well.

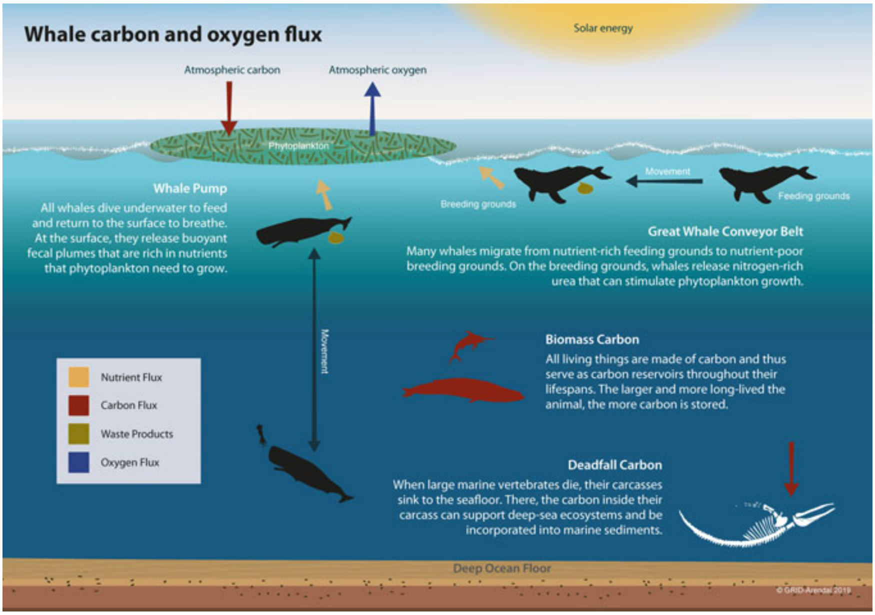
Climate change will also increase the frequency and intensity of marine heatwaves, which have negative consequences for whales. During and after the 2013–2016 marine heatwave in the North Pacific Ocean, also called "The Blob," scientists observed negative effects on humpback whales, such as skinniness and low reproductive rates, likely due to decreased food availability.

Sound: Sound is vital to the survival and health of cetaceans, as they use it to communicate, hunt, and navigate. Ocean acidification due to climate change is expected to alter the chemical composition of the oceans, allowing low-frequency sound to travel over longer distances. This may have both positive and negative effects for whales. Certain whales, such as blue whales, that produce low-frequency sounds may be able to communicate over longer distances. However, noise from human activities such as shipping traffic, sonar, and construction, also occur at low frequencies. As these activities increase, they can interfere with whales' basic survival mechanisms. When boats pass by, scientists have already observed reactions to noise from cetaceans, such as vocalizing more loudly or stopping altogether, just like you would speak more loudly or pause a conversation with someone when a plane or a loud truck passes by. See Chap. 14 for more on ocean noise pollution.

Algal toxins: Harmful algal blooms (HABs) are predicted to increase with climate change. HABs consist of high concentrations of toxin-producing algae that quickly flourish at the ocean surface. Animals at the bottom of the food chain ingest these algal toxins, after which they spread throughout the food web. Two of the main types of algal toxins—domoic acid and saxitoxin—affect the central nervous system and can lead to death. In whales, ingestion of algal toxins has been linked to strandings and ship strikes, likely due to disorientation caused by the toxins.

Typically, HABs occur in tropical and temperate waters, but as the seas warm, HABs will become more common at higher latitudes. In Alaska, the algal toxins domoic acid and saxitoxin have been detected in bowhead, humpback, and beluga whales and harbor porpoise. These toxins have even been documented in the fetuses of beluga whales and harbor porpoise, indicating that their negative effects can be felt even before birth. Not only are HABs bad for the whales, but they can also endanger the communities that rely on these whales for food.

Whale Carbon: How Whales Can Affect Climate Change



Whale carbon describes the biological processes by which whales can remove carbon from the atmosphere. As illustrated below, whales can do this by increasing nutrient availability and thus phytoplankton abundance in the ocean, and storing carbon in their bodies. © GRID-Arendal

Did you know that, unlike humans who through our lifetimes will add carbon to the atmosphere, certain whale species may actually absorb more carbon than they emit during their lifetime? This is called whale carbon and it is an ecosystem service—a benefit freely and naturally provided by whales to humans at no cost.

Whale carbon looks at the biological processes of whales that can help remove carbon dioxide from the air and reduce the effects of climate change. Whales do this in two ways. First, by increasing nutrient availability in the ocean and second, by trapping carbon in their bodies. Through these activities, whales help to change their environment, making them ecosystem engineers.

Whales increase nutrient availability that can help microscopic marine algae, called phytoplankton, to grow. Phytoplankton photosynthesize, meaning that, like plants on land, they use carbon dioxide, water, and sunlight to make the food they need to live and grow. As a byproduct of this process, phytoplankton emit oxygen. Phytoplankton are estimated to contribute at least 50% of all oxygen to our atmosphere—they are critical to the breaths we take each moment. Essentially, if there is more phytoplankton, there is more photosynthesis occurring that takes carbon out of the air and creates the oxygen we need. Phytoplankton are incredibly powerful microscopic soldiers in our fight against climate change. Phytoplankton are also critical to the ocean because they form the foundation of the marine food web, allowing species higher up the food chain to thrive.

How do whales supply phytoplankton with nutrients? First, whales provide nutrients through excretion of fecal matter, or, simply put, they poop. This is called the whale pump because whales bring nutrients to the surface from deep waters where they would otherwise be out of reach to phytoplankton. Whales also transport nutrients horizontally across the ocean during their migrations. This is called the great whale conveyor belt and it can help phytoplankton to grow in areas of the ocean which are typically nutrient poor.

Whales can also help nutrients remain at the surface level for longer than they otherwise would. The movement of a whale in the water—the pump of the fluke up and down, and the swish of the pectoral fins—mixes the nutrients in the water, bringing those nutrients that may be falling to the bottom of the ocean back to the surface so they are available to phytoplankton.

The second way that whales contribute to the reduction of carbon in our atmosphere is by trapping carbon in their bodies that would otherwise be in the atmosphere. Like all living things, whales are made of carbon, and their large body size means they can store a lot of carbon. This is called biomass carbon. A 150 ton blue whale will store roughly 24 tons of carbon in its body during its lifetime. They are also long-lived. In fact, bowhead whales can live for more than 200 years, and the longer they live, the more carbon that is removed from the atmosphere. When whales die, their massive bodies usually sink to the seafloor. This is called deadfall carbon. As the whale carcass decomposes, that lifetime of stored carbon can become mixed with seafloor sediments where it can be sequestered for thousands to perhaps millions of years. This is different from a tree, for example, which cycles carbon into oxygen during its lifetime, but on its death begins to release carbon as it decomposes.

The Positive Impact of a Whale

Scientists have estimated the amount of carbon sequestered as a result of whales and their activities. For example, based on the currently available data for whale falls, global populations of baleen whales sequester approximately 62,000 metric tons of carbon each year. This is estimated to be equivalent to the amount of carbon sequestered by nearly 270,000 acres of US forest in one year. However, commercial whaling has diminished the trapping abilities of whales. Based on currently available scientific evidence, the amount of carbon trapped due to whales would have been at least 10 times higher before large-scale commercial whaling operations.

Concentration of phosphorus, a nutrient needed for phytoplankton growth, is over 700 times higher in a humpback whale fecal plume (circled) than in the surrounding seawater. This acts like a fertilizer that can stimulate phytoplankton growth. Photo taken under NMFS permit #100818-01

Conservation Action

Many whale populations are threatened with extinction and even those whale species at sustainable populations are fractions of what they were prior to industrialized whaling. Increased understanding of the value of whales as ecosystem engineers can help to protect the whales, our planet, and us.

This concept is being recognized internationally, notably at the International Whaling Commission (IWC), which was originally established in 1946 to conserve whale populations for the purpose of their sustainable harvest. In 2018, the IWC recognized the importance of the role of whales in capturing carbon in our oceans in two ways. First, the IWC passed a non-binding resolution on “advancing the Commission’s work on the role of cetaceans in the ecosystem functioning.” This resolution encouraged IWC member nations to “integrate the value of cetaceans’ ecological roles into local, regional, and global organizations on biodiversity and environment, including climate change and conservation policies.” At that same meeting, the IWC, passed another non-binding resolution called the Florianopolis Declaration, which recognizes the that the role of the IWC has evolved to include “the maintenance of healthy cetacean populations to fulfil the vital ecological and carbon cycling roles these animals play in the global marine ecosystem functioning.” These two measures reflect a pivotal shift in perspective from whales being commodities to kill and consume to being partners in our efforts to combat climate change and create a healthier planet, and they are already having ripple effects. Indeed, although not specifically identifying whale carbon, countries have incorporated the conservation of marine biodiversity as part of their Nationally Determined Contributions under the Paris Agreement, because of the ecosystem services and carbon sequestration potential they provide.

In Summary

Whales, the largest animals to ever inhabit the Earth, fill us with a sense of awe and wonder. They are integral parts of Earth’s ecosystems and provide important services to other species, including humans. Yet, whales are facing increasing impacts from climate change and other human-induced threats; the risk of ignoring these impacts on whale populations may be severe.

Robust whale populations are not only important for the cultural and aesthetic inspiration that they bring to the world, but also for their integral role in maintaining healthy ocean ecosystems and assisting in the cycling of carbon. Whale carbon has exciting potential to be a nature-based solution and protecting whales is one of many things we can do to help combat climate change, improve the health of our oceans, and better humanity.

Sperm whales may help combat climate change by absorbing more carbon than they produce throughout their lifetime. However, they are also being affected by climate change. Sperm whales have been observed to be shifting their ranges further northward in Arctic waters. This expansion coincides with an increase in water temperature indicating that climate change is impacting where sperm whales travel. *Credit* Amanda Cotton

What You Can Do to Help

- Spread the word! Whales and their ocean habitat can be our partners in combatting climate change.
- Be a whale—mitigate your own carbon production! There are many online resources to support your journey to reduce your carbon footprint and to a more sustainable lifestyle. Each small step makes a difference; whether it is through your food choices, clothing purchases, travel decisions energy consumption, and/or engagement with your governing officials.
- Support whale-friendly businesses, including, for example, by eating in whale-friendly restaurants in areas where commercial whaling continues (https://www.ifaw.is/about-the-campaign/), by not purchasing krill products in order to protect whales' food base, and by choosing whale-watching companies that operate in a respectful manner (https://worldcetaceanalliance.org/responsible-whale-watching/, https://whalesense.org/).
- Engage in global movements that consider the blue carbon and ecosystem services of marine life in our oceans. Support legislation in your country that

furthers research and incorporates the consideration of whales' roles as ecosystem engineers into management and legal systems.

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Natalie Barefoot Growing up inland, my passion for marine mammals, whales in particular, was ignited by some inexplicable, innate curiosity that drew me to watch ocean programmes, cover my bedroom walls with posters of whales, and fill my bookshelves with ocean-related books. Yet, I never thought I could work for the oceans and ocean animals as a career. Try as I might to not believe it was possible, the calling was too strong to ignore. This made my path to becoming an international ocean lawyer a winding, twisty route rather than a straight line. My work has taken me to five continents and spanned corporate law, academia, non-profits, and international governmental organizations, including the United Nations Environment Programme. Each turn in my career has allowed me to learn skills and tools that are essential to my work today. I assist and speak up for ocean creatures in a way that strives to be earth-oriented, community-inspired, and respectful of all living beings. My work focuses on legal strategies through the lens of keystone species, such as sharks and cetaceans (whales, dolphins, and porpoises), and advancing protections for wildlife and their ocean habitats. I currently tackle international ocean issues as an attorney with Earthjustice and as a volunteer with Cet Law.

Dr. Heidi Pearson From saving the mountain gorillas to saving the whales, animal conservation has been a passion of mine for nearly as long as I can remember. Interconnected with this was a desire to understand the behavior of animals, particularly their social lives. Growing up in Des Moines, IA, I was surrounded by neither rainforest nor ocean, but a high school marine biology class and travel experiences to East Africa and the US coastline helped to set my course. As an undergraduate at Duke University, I explored my interests in both primates and marine mammals. During my graduate research at Texas A&M University, I honed my focus to the behavioral ecology of marine mammals, studying the reproductive behavior of territorial male sea otters for my Master's, and the social dynamics of dusky dolphins for my Ph.D. I have since expanded my studies to the ecology and conservation of various whale and dolphin species across North America, Europe, and New Zealand. Since 2011, I have been a marine biology professor at the University of Alaska Southeast where undergraduate teaching and graduate student advising complement my research.

Part II
Fisheries and Food from the Ocean

Chapter 6
State of the World's Fisheries—Legal Overfishing

Rebecca Hubbard

Fishing: The Biggest Pressure on the Ocean

Fishing has been around for as long as humans have, but it has changed dramatically over time. For hundreds of years, we believed that the ocean was plentiful and that there were too many fish for humans to have an impact. Yet by the nineteenth century, our impact was already becoming apparent, as fish populations nearer to shore became depleted and fishing boats had to go further away, for longer periods, to catch fish. Improved technologies, in terms of engine power, on-board freezing capacity and fish finding technologies, have all enabled fishing boats to catch fish more efficiently. In fact, after World War II, accrued military capacity accelerated the ability to overfish the ocean. With all the technologies available now, there is nowhere for fish to hide. Entire marine ecosystems and associated wildlife have been decimated with ruthless effectiveness. Scientific consensus is that the fish and marine life left in the ocean are a shadow of its former self.

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Credit Eero Aro (in the picture), 1987

Credit Peter Ljungberg, SLU Sweden, 2018

These photos depict the same species. They show the decline in size of fish over time. They show clearly how our perception of a "normal" catch changes over time—the "shifting baseline". The first photo depicts a haul of large cod taken in the

Southern Baltic in 1987. The second photo depicts a skinny Baltic cod, which we consider a normal size today.

It is estimated that we have already fished out 90% of top oceanic predators such as sharks, tunas and swordfish, compared to some one hundred years ago. The result of decades of overfishing is a phenomenon called "fishing down the food web". As top predators are fished out, fishers seek animals lower down in the food chain.

In fact, a landmark report published in 2019 by the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services, concluded that over-exploitation, in other words overfishing, has the biggest impact on ocean biodiversity.

Over the years, The United Nations Fish and Agricultural Organisation (UN FAO) has been assessing the state of the world's fisheries, including wild caught fish as well as fish produced through aquaculture. Whilst the FAO have been reporting sharp declines in fish capture of certain species, the severity of overfishing has been masked by aquaculture, which has been steadily increasing over the years. The 2020 State of World Fisheries and Aquaculture report from the UN FAO suggests that an all-time high of 179 million tonnes of fish were produced in 2018. But aquaculture accounted for 46% of this, and wild caught fisheries have instead been at similar levels since 1988, despite increases in fleet capacity and fish finding technologies. In fact, the United Nations estimates that at least 34% of the world's fisheries are overfished, while 60% of fisheries are fished to their maximum limit, and just 6% are under-fished. In some places, the situation is far worse, for example, over 90% of Mediterranean fisheries are considered overfished.

FAO statistics are believed by many working in fisheries to be conservative, because they do not include estimates of Illegal, Unregulated and Unreported (IUU) catches (see Chap. 7 on Fish Crimes), or the many hundreds of fish populations for which there is limited scientific data. They do not include important assessments such as population age and structure, which means the demographics can be skewed and unhealthy, even though the overall number is fine.

Overfishing does not only impact fish populations, but it can have devastating effects on marine ecosystems and people alike.

Examples of these effects include:

- Breaking down food webs by removing prey (food) for larger species, thus starving predators such as seabirds, seals and sharks.
- Overfishing the fish at the top of the food web removes large predator species so that there are more prey species than naturally occur, which has knock on consequences down the food web.
- Removing too many fish that eat algae, leads to increases in algal blooms, which can have devastating consequences for marine ecosystems.
- Impacting the ocean's capacity to absorb carbon dioxide and converting and transporting carbon to the seafloor for sequestration (storage). Marine life forms the ocean's so-called biological pump.
- Damaging and destroying important marine habitats such as seagrasses, kelp, corals, seamounts and sponge gardens, which have multiple benefits discussed elsewhere in this book, and which are important breeding and feeding areas.

- Less food available for people, especially for communities that fish locally and who depend on fish for their livelihoods.
- Decreasing profit margins, as fishers have to travel further or for longer, using more fuel and time.
- Reducing the number of jobs that can be sustained by fishing, due to decreased natural wealth.
- Impacting on coastal communities by decreasing the economic benefits derived from the sea as well as impacting on human well-being.
- Decreasing the ocean's resilience to other stressors, including climate change.

How Can Overfishing Be Legal?

Overfishing is widely recognised as a problem and governments from around the world have committed to ending overfishing in numerous forums for decades. Some global agreements that nations have signed on to include:

- In 1982, 158 countries signed the United Nations Convention on the Law Of the Sea (UNCLOS) committing to address overfishing;
- At the 1992 Rio Earth Summit, 150 governments signed onto the Convention on Biological Diversity;
- In 2015, all member states of the UN adopted the Sustainable Development Goals (SDGs), including SDG14 which is dedicated to protecting life below water; and
- In 2020, 88 national leaders from across the world and the EU signed the Leaders Pledge for nature to reverse biodiversity loss.

Adherence to these agreements would go a long way to addressing the problem of overfishing. However, most pledges made by governments are not legally binding, which means that ignoring these global agreements does not make overfishing illegal. Where fishing limits and regulations are put into law, governments put short-term profits and politics ahead of science, with little to no accountability. Governments try to negotiate with nature's limits, with little success. Even in places like the European Union, where national laws require that they must end overfishing by 2020, governments continue to ignore scientific advice and set fishing limits too high.

Overview of Fishing Techniques

Fishing takes many forms, from anglers and recreational fishers, to small-scale fisheries. Some four million fishing vessels plough the world's ocean every year. Of these, most are small boats and operations, with lesser or more impact on fish populations and ecosystems. Whilst small-scale vessels (as well as recreational fishing) can also cause immense damage to local marine ecosystems and fish populations, particularly when considering their collective impact and the fact that their activities are less well monitored, the global problem of overfishing is largely down to the industrial scale fleet. Industrial fishing vessels are generally considered large vessels over 24 m long, but they can also include vessels over 12 m long using "active gear" (see below). There are some 180,000 industrial boats fishing the global ocean. These vessels are categorised by their fishing techniques and gear type.

Industrial fishing by wealthy nations in particular, dominate the world's oceans. *Credit* Pierre Gleizes/Greenpeace

Trawling

Mid-water trawling, including pair trawling, is a highly efficient way of catching as many fish as possible as quickly as possible. For pelagic species (fish that live in the water column), like mackerel, sardinellas, herrings, anchovies and sea bass, trawling is done by the deployment of a net behind a school of fish that is pulled through the water column by one or in the case of pair trawling, two boats.

"Super trawlers" are the largest and most efficient fishing vessels to comb the seas. They have nets that are big enough to hold 13 jumbo jets. They are factory trawlers that immediately process and freeze the catch. Europe's largest trawler is 144 m long and can catch around 250 tonnes of fish a day, and hold 7000 tonnes onboard. The catch of these trawlers is often sold and used as fish food for aquaculture, contributing to an even greater ecological problem (see Chap. 8 on Aquaculture). Pelagic trawlers are known to accidentally catch protected species like dolphins and sharks, which eat the schooling fish.

Bottom trawling is used to catch demersal species (fish living on, in or near the seafloor) and is known as one of the most destructive fishing gears. Bottom trawls drag heavy nets over the seafloor. The nets are weighted down by heavy chains and rock hoppers, and destroy almost everything in their wake. In addition to the target species, bottom trawlers catch a wide variety of fish that are then thrown back dead or dying. This unwanted fish is known as bycatch. Bottom trawls cause enormous damage to habitats and the seafloor, destroying plants, corals and other creatures that may have taken hundreds or even thousands of years to grow. Bottom trawling is likened to clear-felling a forest on land for the sake of catching a few birds.

Case Study

European seas are the most bottom-trawled in the world. The EU estimated in 2011 that their fishing industry caught and threw away 1,700,000 tonnes of fish each year as "unwanted bycatch". During the winter of 2018–2019, it is estimated that 11,300 dolphins were killed by fishers in the Bay of Biscay alone.

Purse Seining

This type of fishing deploys a net that is weighted down, and as it surrounds the school of fish, is pulled closed at the bottom, much like a purse string. The nets range in size and can be up to several hundred metres wide and tens of metres deep. Purse seines target herring but also tuna species such as skipjack and bluefin tuna. Purse seining can be a sustainable method of fishing, in terms of limiting bycatch, and if done on a small-scale. Unfortunately, the size and scale of the purse seine fleet, in for example tuna fisheries, have resulted in the overfishing of many tuna populations around the world.

Moreover, some purse seine fisheries further deploy fish aggregation devices or FADs. These are floating objects, for example, a steel barrel that can be anchored, or left to drift, in which case they are equipped with a global positioning system (GPS). FADs attract an entire ecosystem. The smaller fish seeks shelter from the open ocean under a FAD and feed on growth such as barnacles or algae that attach to the FAD. These fishes in turn attract larger fish and eventually tuna, as well as dolphins, sharks, sea turtles and seabirds. Purse seiners then very efficiently deploy a net around the schooling tuna and catch everything. Tens of thousands of FADs have been deployed. Whilst they can assist fishing in near shore local fisheries, their deployment in the open ocean is largely unregulated, pose a navigational hazard to other vessels, and because they are so effective at encouraging tuna to school, help drive overfishing.

Gillnets

Gillnets are vertically deployed nets buoyed at the surface and weighted down. They are either anchored or left to drift. These nets are left alone for a period of time and then pulled up. They can vary in size and length, and anything that swims into it is caught. Large industrial scale gillnets are often referred to as walls of death. Fish, including sharks as well as dolphins and other marine life, gets entangled and often die a slow, torturous death. Drift nets longer than 2.5 km have been banned by the United Nations in the high seas and are sometimes regulated (or illegal) in national waters.

Longlining

Longlines are essentially long fishing lines with baited hooks attached. Depending on the fishery, long lines can range from a few hundred metres to well over 100 km long—the average U.S. longline set is 45 km long. The longer lines can have several thousand hooks on them, and depending on the target catch, are weighted down, sometimes to the seafloor. It has been estimated that enough long lines are set to wrap around the globe 500 times every day. Longlines target large pelagic fish such as tuna and swordfish or demersal fish like cod and Patagonian toothfish (also known as Chilean Seabass). They can be extremely dangerous for seabirds, sharks, turtles and other non-target fish species, which are attracted by the bait and get caught.

The impact of fishing gear can last for years or even decades. For example, if they break and are lost at sea, fishing gear can continue to kill for years. This type of unintentional fishing is known as ghost fishing. See Chap. 11 on Plastic and the Ocean for more on the devastating impact of fishing gear as waste in the ocean.

Distant Water Fishing

As nations deplete fish populations in their own waters, their fleets go out looking for richer fishing grounds in distant waters. With the movement of fishing vessels across the oceans, regulations attempting to manage these vessels as they move between waters and international waters are patchy at best. Chapter 20 covers how we govern the world's oceans, including fishing in international waters. When it comes to national waters, fishing nations may seek partnership agreements with countries whose waters they wish to fish in. For example, several EU and Asian nations fish in West African waters, or in the sovereign waters of Pacific Island Countries, and have established Fisheries Partnership Agreements with the relevant coastal states. However, these partnerships are often not equitable, with fishing nations depleting the new fishing grounds, competing with local fishers, and often only paying a fraction of the true value of that fishery.

Transforming Our Relationship with Fish—What We Can and Must Do

Fisheries management has been the source of furious debate among scientists, conservationists and policy makers for many years. What is clear is that we now understand that fishing has a huge impact on ocean health and its capacity to provide important ecosystem services to support life on the planet, and so we must do a better job of managing that impact.

Ecosystem-Based Management: Government Solution

As our understanding of the impact of fishing has increased, management approaches have changed. Although many systems are still dominated by managing "single species" (with fishing limits only set for the target species), many governments have acknowledged that we need to take an ecosystem-based approach to fisheries management. This means that other ecosystem impacts are minimised when setting fishing rules, which can include overall fishing limits, restrictions on gear types or restrictions at certain times or places. These ecosystem considerations can include:

- Minimising impacts on the food web (ensuring there is enough prey food for predators like bigger fish or sharks);
- Minimising impacts on sensitive or protected species (such as seabirds or dolphins);
- Minimising impacts on habitats (such as the seabed, seagrass or corals);
- Avoiding bycatch of juvenile fish, in order to ensure they can grow and reproduce;
- Designating a network of permanent marine protected areas as well as seasonal closures based on scientific advice;
- Improving resilience to climate change by rebuilding fish populations or minimising impacts on habitats that can help adapt to climate change impacts (e.g. mangroves, seagrasses);
- Improving the ocean's capacity to mitigate climate change by restoring fish populations to increase their capacity to sequester more carbon, or to minimise damage on carbon-rich seabeds.

With the rapidly worsening cumulative impacts of climate change and pollution, combined with overfishing, ecosystem-based management is urgently needed and is the responsibility of governments.

Stewardship and Transparency: Industry Solution

While fishers have long been seen as the stewards of the sea, a lack of transparency as well as illegal and destructive activities, have damaged this reputation. With increasing consumer awareness of how food is produced, the fishing industry is becoming more aware of the need for a social licence—to be able to show that they are responsible managers of a public, natural resource. Fishing companies can demonstrate they are stewards of the sea by:

- Agreeing to electronic monitoring at sea, demonstrating they catch what they report;
- Adopting selective gear that avoids catching protected species, juvenile fish and damaging sensitive habitats and the seabed;
- Picking up and bringing back rubbish and plastic waste from sea;
- Joining co-management schemes to help manage their fisheries in local areas;
- Supporting the need to set fishing quotas in line with scientific advice, and adhering to that advice.

Choosing Sustainable Seafood and Campaigning: Individual Action

Fish discarding. *Credit* Western Sahara Resource Watch

With increasing awareness of the devastating impact of food production on our environment, consumers are increasingly demanding sustainable food. Billions of people depend on seafood for their primary source of protein. However, many of us can make the choice to either abstain from eating seafood or choose to eat seafood wisely. Local and seasonal issues can make a big difference on your choices. Look up your local NGO or Sustainable Seafood Guide, and if one does not exist, do your own research:

- What fish is overfished in your area? Avoid them.
- What fish is sustainably managed or has a healthy population? Better choice.
- What is the minimum size for the fish you like to eat? (Don't buy baby fish!).
- Ask what gear the fish was caught with—avoid fish caught with bottom trawls or longlines.
- Meet your local fishers, and try to buy fresh fish direct from them (if they satisfy the above questions).
- Catch your own with low-impact methods—but make sure you get a licence and target the ones that are healthy.
- Avoid farmed fish that are fed other fish.

See Chap. 10 for more information about the move to sustainable seafood.

Further Reading

Callum Roberts, Unnatural history of the sea.
Greenpeace, Monster Boats: The scourge of the oceans.
Isobella Lövin, Silent Seas: The fish race to the bottom.
Jennifer E. Telesca, Red Gold: The managed extinction of the giant bluefin tuna.
Mark Kurlansky, Cod: A biography of the fish the changed the world.
Rachel Carson, The sea around us.
World Bank Group, The Sunken Billions Revisited: Progress and challenges in global marine fisheries.

Rebecca Hubbard I was born on the south-east coast of Australia and grew up climbing trees and swimming at the beach. I received an Honours Degree in Environmental Science at the University of Wollongong, worked in government super briefly and then converted to activism. I volunteered, blockaded, and worked on environmental issues from ancient forest logging to genetically engineered foods, and then moved to Western Australia to help protect Ningaloo Reef. It was there that I learnt to surf and discovered that the "other 70%" of the planet was being systematically destroyed but was severely under-defended. I committed to the blue—working for marine sanctuaries, coordinating an alliance to stop super trawlers entering Australia, and in 2017, started the campaign Our Fish to end overfishing in Europe (*Credit* Dave Walsh).

Chapter 7
Fish Crimes (Illegal, Unreported, and Unregulated Fishing)

Farah Obaidullah

Introduction

As we have read in Chap. 6, overfishing compromises ocean health. More animals are removed from the ocean than can be replenished, and destructive fishing gears can destroy marine habitats. As the global community grapples with the need to bring fishing in line with the ecological limitations of the ocean, there is another side to the industry that exacerbates the already perilous state of world fisheries: illegal, unreported, and unregulated fishing, or IUU fishing. It is estimated that each year IUU fishing costs the industry a whopping 23 billion or more euros worth of fish. This translates to approximately one in five fish being caught illegally. IUU fishing wreaks havoc to life in the ocean, severely undermining any management and conservation efforts, and is devastating local communities and legitimate fisheries the world over. IUU fishing often goes hand in hand with other crimes including environmental and wildlife crimes, smuggling of contraband such as drugs or weapons, money laundering, human trafficking, and labour abuse and slavery at sea. The global scourge that is IUU fishing has finally, in the last two decades, caught the attention of governments and the media. As governments have come to recognise the economic loss to their own national fishing fleets and economies, they have started to work at the international level to try and address IUU fishing. Technologies are emerging to help tackle fish crimes. However, patrolling and enforcement of an elusive industry that happens out of sight in the vast open ocean remain incredibly challenging.

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What is IUU Fishing?

The term IUU fishing was first coined in the 1990s and is defined as follows:

Illegal Fishing (I) is fishing that occurs in violation of existing laws pertaining to fishing either in national waters or on the High Seas (international waters), such as the laws that govern fishing within areas managed by Regional Fisheries Management Organisations (RFMOs). In national waters, illegal fishing can be conducted by vessels either flying the flag of that state or a foreign flag. In international waters illegal fishing is conducted by those vessels flying the flag of states that are parties to the relevant RFMO and therefore bound to those laws, and who violate those laws.

Examples of illegal fishing include targeting fish for which the vessel operator has no licence, using prohibited gear or gear that is not in compliance with the law (e.g. too small mesh size or too large nets), catching undersized fish and fishing in areas that are off limits to fishing either permanently or temporarily (marine protected areas).

Unreported Fishing (U) is fishing that has not been reported or that has been misreported, either nationally or to the competent international authorities such as the RFMOs. Examples of unreported fishing include underreporting catches. A vessel may be fishing beyond their quota and not reporting the excess catch. Misreporting essentially violates the relevant reporting procedures. Some rogue vessel operators engage in a practice known as "high grading". This is when they continue fishing to replace less than optimal fish with higher-quality fish. That vessel may have reached its quota but continues to fish to optimise the quality of its catch. This wasteful practice means that the true catch of a certain species by that vessel is not reported. Illegal discarding, which is when a vessel illegally throws unwanted catch or bycatch back overboard, is also a form of unreported fishing.

Unregulated Fishing (U) is all fishing that occurs that is not subject to any laws or regulations, for example, fishing in international waters by vessels flying a flag that is not party to the relevant fisheries management body (RFMO). By virtue of their flag, these vessels are not bound to the applicable rules and regulations. Unregulated fishing includes targeting fish for which there are no applicable management or conservation measures. Fishing activities that are inconsistent with the flag state responsibilities for the conservation of living marine resources under international law are also considered unregulated fishing.

Labour Abuse and Slavery at Sea

Bunk conditions onboard a purse seiner operating in the High Seas of the Western Central Pacific Ocean. *Credit* Paul Hilton/Greenpeace

The rising demand for cheap seafood drives overfishing globally, but it also comes with immense social issues. Overfishing forces vessels to fish further from their traditional fishing grounds including into the High Seas. This means higher operating costs including costs for improved technology, access and licensing fees, and fuel. One way industrial fishing vessels keep overheads down and seafood cheap is to break existing management and conservation rules, i.e. engage in IUU fishing. Another way is to exploit labour. Working conditions aboard fishing vessels are among the worst in the world. Crew can encounter a whole spectrum of issues from extremely low wages, lack of sanitation, lack of safety equipment, and lack of personal space to long working hours, forced labour, human trafficking, and even murder at sea. Once a vessel leaves port, it is very difficult to monitor what happens onboard. Vessels can spend months and sometimes years away from port. Ships at sea provide the perfect setting for labour abuse to occur.

Labour abuse and forced labour are not limited to any one nation's fleet, although the highest incidences documented and reported concern migrant workers from South East Asia. Workers can board fishing vessels with no idea that they will be forced to stay out at sea for months and sometimes years at a time. These workers find themselves misled and tricked by recruitment agents. Some never intended to work at sea. They are often migrants with a nationality other than that of their vessel operators. Their papers are taken away from them and being at sea means they cannot escape, let alone communicate their situations. Often not speaking the same language or sharing the same culture as senior crew, the workers are stripped of all human dignity, forced to work long days without adequate rest, sharing bunks in cramped quarters, and with little to no access to sanitation. These men and boys set out to find work to support their families only to lose contact with their loved ones for long stretches of time, able to send back a fraction of what they were promised if they even get that opportunity.

What Enables IUU Fishing?

The fact that the ocean is so vast and makes up most of our planet goes a long way to explaining how challenging it is to clamp down on and eliminate IUU fishing. The sheer size of the ocean and the lack of eyes on the ocean make it a playground for criminal activities and those tempted to flout the rules. But there are certain legitimate practices that facilitate IUU fishing.

Flags of Convenience (FoCs). Every vessel must be registered to a country and fly the flag of that state. Flying a Flag of Convenience is quite simply a practice where a vessel owner registers its ship in a country other than its own. The use of "Flags of Convenience" or FoCs is not limited to the fishing industry. Usually, the adopted state is one with the least stringent rules in place. In the world of fishing, this country may not be signatory to any international agreements pertaining to fishing or may not be a party to any regional fisheries management organisations. Flying a Flag of Convenience essentially exempts that vessel from internationally agreed upon rules and regulations. Flying a Flag of Convenience not only lowers the bar in terms of fishing compliance but often also means that there are other less stringent laws that the vessel owner is subject to, for example, those relating to safety, labour laws, and even taxes. Within the fishing industry, there is no globally agreed upon or official definition of an FoC, or list of countries that provide FoCs. Moreover, vessels can "flag-hop" between states making it harder to track and trace those vessels systematically evading the rules.

Transshipment. This is the practice of offloading catch on to refrigerated cargo vessels (reefer vessels) at sea. It is a common practice that allows vessels to stay out at sea longer without having to return to port to offload their catch. Transshipment is particularly worrisome on the High Seas, where there is practically no oversight. A reefer engaged in IUU fishing can collect the catch of multiple vessels and can mix catches from fishing boats sometimes operating in different jurisdictions, thereby making it difficult if not impossible to properly trace fish back to the fishing vessel of origin. A fishing vessel engaged in IUU fishing does not report or underreports their catches. That vessel continues fishing, seemingly within its quota, whilst the excess fish is laundered through reefer vessels. Moreover, fish that may be destined in the books for one market easily ends up on another. Transshipment enables other crimes at sea. For example, the smuggling of contraband is facilitated through at-sea transshipment away from the scrutiny of the authorities. Furthermore since the High Seas are still largely lawless, it is difficult to know which authorities have jurisdiction over crimes in a given area there. Transshipment enables fishing vessels to stay out for months and often years at a time. Fishing vessels are resupplied at sea, with fuel, food, and other provisions, either by the reefer vessel or by other resupply vessels. This makes fishing vessels with no need for port calls a perfect setting for labour abuse, or worse, a perfect prison to keep slaves.

Illegal transshipment taking place in the High Seas of the Western Central Pacific Ocean. *Credit* Shannon Service/Greenpeace

A Lawless Ocean

Much of the ocean lies in international waters or the High Seas. In fact the High Seas comprise 64% by surface area of the ocean and do not belong to any one nation. This vast part of the ocean and indeed planet is subject to only a patchwork of regulations. There is currently no comprehensive governance regime that covers the High Seas. As discussed in Chap. 20, a treaty to protect biodiversity beyond national jurisdiction is currently being negotiated and finalised by the United Nations, but it is unlikely that this will address and clarify the jurisprudence of illegal fishing on the High Seas. This lawless nature of the High Seas makes it particularly appealing for criminals and those wishing to fish with impunity.

Tackling IUU Fishing

Technology to Combat Fish Crimes

Advances in technology are helping to unveil fish crimes happening at sea. The International Maritime Organisation (IMO) requires that all vessels greater than 300 GT (gross tonnage) that are on an "international voyage" and in any case all vessels greater than 500 GT have an automatic identification system (AIS) onboard. Although, a flag state may exempt certain ships from carrying an AIS. This system relays information in real time to the relevant authorities about a ship's location. The AIS helps keep vessels safe by supplementing radars and avoiding collisions, but it also allows authorities to keep an eye on where a vessel is operating. A ship's AIS must be on at all times, including at anchor. Some countries and intergovernmental agencies such as RFMOs have an automatic identification system (AIS) requirements for fishing vessels within their waters, for example, the EU requires all fishing vessels beyond 15 m to have an AIS.

Countries also have a requirement for national fleets to have a vessel monitoring system (VMS) onboard. This system relays information back to the national authorities of the vessel's flag state.

Such monitoring tools are essential to understanding how many vessels operate at any given time, and whether these vessels are operating within the law. However, to be effective these systems must be universal, they must be tamper proof and on at all times, and the information must be made accessible to enforcement agencies.

As outlined in Chap. 23 on leveraging innovation for ocean conservation, great strides are being made to use satellite technology to help visualise what is going on in our ocean. Mapping and overlaying data points allow analysts to infer with high accuracy where a vessel has been or what it has done, even if that vessel has temporarily switched off its AIS, for example, determining whether a vessel has engaged in transhipment or whether it has entered a marine protected area.

Steps Governments Can Take to Help Eliminate IUU Fishing

Tuna illegally transshipped onto a reefer vessel. *Credit* Alex Hofford/Greenpeace

As with tackling any crime, it is difficult to eradicate illegal, unregulated, and unreported (IUU) fishing entirely. However, there are some clear steps that can be taken to significantly reduce the amount of wildlife that is taken from our ocean each year through IUU fishing.

- A very simple and highly effective measure to combat IUU fishing and with it, all associated illicit activities, is to ban at-sea transshipments.
- There must be a global effort to eliminate the use of Flags of Convenience (FoCs), for example by mandating a genuine link between vessel owner and flag state.
- The seafood sector must continue to improve and develop enhanced traceability and transparency tools within seafood supply chains, for example through block chain technology.
- Governments and fisheries agencies should get better at sharing information and intelligence. This can be done through:
  - Joining initiatives such as Global Fishing Watch and sharing (fishing vessel) data.
  - Developing and mandating tamper-proof unique identification numbers (or IMO numbers) for all vessels engaged in commercial fishing, including reefers.

  - Establishing an official centralised and enforceable global vessel registry, including a blacklist of vessels. For example, whilst RFMOs maintain their own vessel registries and black lists of vessels that have engaged in IUU fishing, this list is not centrally or universally enforced, for example by flag states and/or port states. This means that fish criminals caught in one area of the ocean can move to another area with impunity.

- The international community already has several instruments at hand that if implemented and enforced properly would greatly deter and prevent fish crimes from happening. These instruments include:

  - The Port State Measures Agreement (PSMA). Ports are the gateway for IUU caught fish to reach our markets. In 2009, the United Nations Food and Agricultural Organisation (FAO) approved the Port States Measures Agreement, which entered into force in 2016. This agreement was the first legally binding instrument to prevent, deter, and eliminate IUU fishing. All countries should ratify and implement this agreement immediately. Recognising that not all countries have the same capacity (funding and training for example) to implement and enforce the PSMA, the global community must come together to address any gaps.
  - Work in Fishing Convention C188. This convention was adopted by the International Labour Organisation (an agency of the UN) and entered into force in 2017. It is meant to ensure a basic universal standard of decent working conditions onboard all commercial fishing vessels. This standard covers food and accommodation, occupational health and safety, medical care, and social security. Setting such standards facilitates labour inspections in port. Unfortunately, this convention has yet to be ratified by the majority of nations.
  - The IMO Cape Town Agreement, which includes provisions around the safety and integrity of vessels including equipment onboard.
  - The FAO Compliance Agreement, which has a special emphasis on flag states responsibility to ensure that none of their vessels are fishing on the High Seas unless authorised.
  - The FAO International Plan of Action to Prevent, Deter and Eliminate IUU fishing. Whilst voluntary, this sets out some important comprehensive steps that if followed would make it difficult for illegal fishers to flout the rules and gain access to seafood markets both nationally and internationally. For example, it includes steps around monitoring, control, and surveillance, national, regional, and international cooperation, flag state responsibilities, technical compliance, vessel registries, and more.
  - There are also national and regional tools available that, whilst not perfect, help raise the global standard for fighting IUU fishing, including labour rights violations, for example, the EU rules to combat IUU fishing, the EU Fisheries Control Agency, and the US Trafficking in Persons country designations, to name a few.

– Market players have also come together to set standards for suppliers to access their markets. Some industry associations too have been establishing guidelines on transparency and traceability in seafood supply chains. See Chap. 10 for more on the move towards sustainable seafood.

Successfully fighting IUU fishing comes down to political will. If governments are serious about tackling fish crimes, they must get better at implementing and enforcing the rules already established. But beyond that there needs to be better cooperation and sharing of intelligence between nations and agencies, as well as a strong comprehensive global treaty for activities happening on the High Seas. Whilst international agencies such as Interpol are sometimes engaged to help track down and bring to justice fish criminals, their authority and jurisdiction are limited. Until there is an authoritative international policing system for the global ocean and an obligation to share (fishing vessel) data between countries, there will be too many loopholes for rogue fishers and fish crime syndicates to exploit.

First Hand Account—Farah Obaidullah

I have spent many years campaigning against destructive and illegal fishing practices, witnessing first hand some of the most egregious practices happening at sea. From the wasteful discarding of endangered species such as sharks and turtles, and the discharging of oil and other pollutants to sea, to the harrowing working conditions on fishing boats.

On my expeditions at sea, it was common for us to board fishing vessels. Our mission was to inspect and document these vessels. Were they licensed to fish where they were operating, did they keep proper logbooks, were they tampering with their vessel monitoring systems (VMS), how much did they catch, both on and off the books, including bycatch of animals such as sharks, and so on. On our visits, we would observe the working conditions, and where possible ask the crew some basic questions about where they were from and how long they were at sea for and their treatment onboard. On almost all my boarding of tuna longline vessels and purse seine vessels out on the High Seas, I would be appalled at the conditions onboard. Several men were sharing a single thin mat for a bed and sleeping in shifts. Sometimes the mats were tucked underneath a ledge, often in an extremely hot part of the ship, near the engine. The ships were infested with cockroaches and vermin. Often the men had been away from home for months if not years.

Man without scuba or safety gear corralling fish inside a purse seine net. *Credit* Alex Hofford/Greenpeace

As a safety diver, I accompanied our camera crew to document fishing activities underwater. On one occasion, we were diving at a depth of about 23 m (just over 75 feet) alongside a purse seine net filled with predominantly skipjack tuna (the kind mostly sold in cans). At first, I was taken aback by the blood coming out of the nets and the stress that the tuna were clearly experiencing. Then to my horror, I saw a human foot protruding from the net. Many thoughts went racing through my head. Was this a dead body in the High Seas? As the expedition leader, how should I deal with this? Then, a face emerged and it was clear that the man was alive and in fact working. Swimming among thousands of stressed tuna without any protective gear or even basic scuba gear, the man had a hose clenched between his teeth coming down from the ship supplying him with air. How do you hold on to that in a frenzied school of tuna? I wondered. No fins, no buoyancy control device, no regulator. The man's job was to corral the fish in the purse seine net and into the smaller scooper net that hauls the catch onto the boat. After surfacing, we requested to board the purse seiner, and whilst this vessel was legitimate, the working conditions were extremely hazardous. The man from the net showed me where he got his air supply. It was a rusty looking compressor, and there was no way to monitor the air quality or composition.

On another occasion, our crew bore witness to a transshipment happening on the High Seas in the Western and Central Pacific Ocean, involving multiple catcher vessels and a reefer flagged to Cambodia. We boarded and inspected the reefer to find that the captain kept no logbooks detailing the transfer of catch, how much and from which boat. No crew manifests and no details even of the ships that he was offloading from. I was used to boarding ships with a bridge filled with high tech screens, radars, and communication gadgets. This ship had the bare minimum. No screens and no gadgets. The captain had a handheld Global Positioning System (GPS) and a satellite phone. He took orders from his boss on land who would call him with the coordinates of where to go. It was as simple as that. The ship's hold, the size of a basketball court, several metres high, was three quarters full mostly with skipjack tuna, and there was no way of knowing where any of it was caught or by whom. The fact that we were on the High Seas and that the reefer was flagged to a country that was not a member of the Western and Central Pacific Fisheries Commission (The RFMO charged with managing tuna in that area), made it impossible for us to alert anyone with authority. The closest territorial waters and therefore country was Palau. For the entire expedition, we had Palauan enforcement officers onboard, even whilst this incident unfolded. I made a call to the attorney general's office of Palau and as expected Palau, although willing, was powerless to act. I made the point that the ship would be passing through Palauan waters on its way to the Philippines and still Palau was unable to act. We trailed the ship for a few days and witnessed it changing name. They had also conveniently covered their IMO number. This is a number that is unique to the vessel and should not change even if the name or flag does. This case illustrated all too well the lack of governance on the High Seas and the desperate need for better international cooperation. We had all the information about the vessels in question, including visual evidence of transshipment, lack of proper catch data, and documented the overt change of name as well as dumping of fuel at sea. We knew where the ship was destined for and yet there was nothing we could do and no one we could alert, to stop this illegal catch from reaching the global tuna market.

What Can You Do to Help Eliminate Fish Crimes?

- The actions here are very similar to those outlined in Chaps. 6 and 10. The basic action you can take is to know what you eat. If you choose to eat seafood or eat seafood out of necessity, do your best to find out where your seafood comes from.
- Support initiatives and non-profits that help tackle IUU fishing.
- Importantly, as with all the critical issues facing the ocean, use your voting power to elect those that genuinely want to improve the state of the ocean.

Further Reading

Initiatives, Non-profits and Reports

Environmental Justice Foundation. https://ejfoundation.org/what-we-do/ocean/ending-illegal-fishing
Fishy Business. How transhipment at sea facilitates illegal, unreported and unregulated fishing that devastates our oceans. Greenpeace, 2020.
Forced Labour At Sea: The case of Indonesian Migrant Fishers. Greenpeace, 2021.
Global Fishing Watch: An initiative that uses technology to advance ocean governance through increased transparency of human activity at sea. Globalfishingwatch.org
TM-Tracking (TMT). TMT provides national fisheries authorities and international organisations with fisheries intelligence and analysis, to assist enforcement actions and broader improvements in fisheries governance. Tm-tracking.org

Books

Fishers and Plunderers. Theft, Slavery and Violence at Sea. Alastair Couper, Hance D. Smith and Bruno Ciceri. PlutoPress, 2015.
Outlaw Ocean. Crime and Survival in the Last Untamed Frontier. Ian Urbina. Vintage, 2020.

Movies

Ghost Fleet. 2018. A heart-wrenching documentary film that follows one woman's quest to seek justice for men forced into slavery at sea. (See Chapter 32 on Inspiring Voices and the profile of Patima Tungpuchayakul).

Farah Obaidullah I have been passionate about the ocean since as far back as I can remember. From picking up litter on the beach to exploring life in the shorebreak, my destiny to work for the ocean was sealed at a young age. I completed both my undergraduate and master's degrees from Imperial College in London. After four years of working as an environmental consultant, I redirected my career towards the ocean. I have spent the last 18 years campaigning for healthy oceans. My work has allowed me to travel the world, observing the beauty of the ocean and witnessing some of the most awful practices happening at sea. I have worked on a whole range of ocean issues. Among others, I have executed campaigns to end destructive fishing, worked with affected communities, lobbied for ocean protection, and exposed fish crimes, including slavery and labour abuse at sea. I am currently campaigning to secure a moratorium on deep-sea mining. Deep-sea mining is an emerging threat that we know will cause irreversible damage to the ocean. Unlike other destructive practices, we can still (at the time of this writing)

prevent deep-sea mining from going ahead. I am biracial, bicultural, and consider myself a citizen of the world. I strongly believe that by embracing our human diversity we can turn the tide for our ocean planet.

Chapter 8
Aquaculture: Farming Food from the Sea

Kelly Roebuck

Introduction

Today, around half of our seafood comes from aquaculture or farmed seafood. By annual growth rate, aquaculture is the world's fastest growing food production system. In 2020, aquaculture contributed 87.5 million tonnes of aquatic animals to the global seafood supply chain. This exponential growth has been met with environmental and social challenges that, in turn, have fuelled debates on wild versus farmed seafood and whether all farmed seafood is 'good' or 'bad'. However, just as not all fishing is necessarily bad, so is the same for aquaculture. When done right, aquaculture has the potential to become a viable solution to the increasing demand placed on our oceans by an ever-growing world population—but to do so, it must be done responsibly and not at the expense of our marine ecosystems. Simply put, what we farm and how we farm it matters.

Farming Seafood as a Solution to Overfishing

According to the United Nations Food and Agriculture Organization (FAO), about a third of global fish stocks are overfished. Aquaculture has been hailed by many, including the FAO, as part of the solution to overfishing. This is based on the hypothesis that fishing pressure on wild stocks is reduced when shoppers purchase farmed

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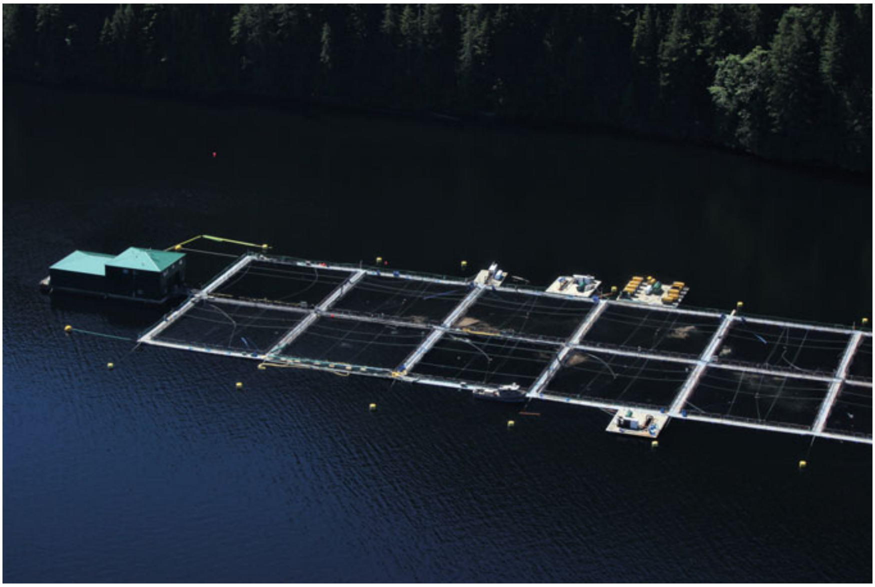
seafood over wild-caught. Or in other words, eating a farmed fish saves a wild fish. If correct, comparing farmed seafood production against wild-caught production over time should show a correlation between aquaculture's rise with a decline of wild fish captured. In actuality, researchers have found wild fishery production has remained relatively stagnant over the last four decades as aquaculture production steadily grew. This means that aquaculture supplements, not suppresses, wild fishery production.

A major driver for this lack of wild fish reprieve is the use of fish to feed fish (and to a lesser extent livestock such as pigs and poultry). Every year, so called 'reduction fisheries' catch millions of tonnes of 'forage fish', from mackerel to sardines to the small crustacean krill, with almost 70% destined to be converted to fishmeal and fish oil for animal feed—including most of the catch of the largest fishery in the world, Peruvian anchoveta (*Engraulis ringens*). Yet, these little forage fish plays big pivotal roles in sustaining marine ecosystems. The removal of these low trophic species from the ecosystem can have cascading impacts on higher trophic species, such as larger finfish (for example tunas, swordfish and sharks), sea birds and marine mammals, that depend on them for survival.

Increasing demand for wild fish for feed, with supply largely confined to finite reduction fisheries, has led to rapidly increasing prices for fishmeal and oil. These high prices have caused the aquaculture industry to seek alternative and more affordable feed ingredients to wild fish. Fish feed today now utilizes a growing number of plant protein sources such as soy, wheat, grains and seeds. By-products from livestock and seafood processing have also been incorporated into the mix. Some manufacturers have even invested in novel ingredients such as insects, yeast, single-celled proteins and algae. As a result, Fish-In-Fish-Out ratios have substantially progressed over the last decades. For example, in 1990, it required 4.4 kg of wild fishmeal and 7.2 kg of wild fish oil to produce 1 kg of farmed salmon. In 2016, it required 0.8 kg of wild fish meal and 1.5 kg of wild fish oil.

However, while fish feed manufacturers have innovated over recent years, the reality is, in 2018, 18 million tonnes of wild fish were extracted from our oceans for aquaculture (or 27% of the global marine catch), and with significant expansion forecasted for aquaculture, there will be further demand for marine feed ingredients into the foreseeable future.

Consumer eating preferences in the 'Global North' don't help. These markets tend to prefer high-value, carnivorous and environmentally intensive farmed seafood, like salmon and shrimp. This demonstrates *what* we farm matters. In stark comparison with the farming of carnivores, farmed shellfish, such as mussels and oysters and aquatic plants, such as algae and seaweed, require no feed at all.



Aquaculture net pen. *Credit* Kelly Roebuck

Why Seafood Farming Practices Matter

How we farm also matters. Like land-based agriculture, farming practices and methods determine an aquaculture farm's overall environmental impact. Weak laws and oversight by government agencies tasked with regulating the industry can further exacerbate impacts. Some types of farming methods have more potential to cause harm than others. Cages or net pens are often associated with negative impacts to wild species and habitat as their open design allows for free flow between farm and wild environments. These systems are more prone to farm escapees which can outcompete or interbreed with their wild counterparts. They can act as reservoirs for disease and parasite transfer between farmed to wild species. Open systems freely release pollution including chemical and waste effluent such as faeces, feed and antibiotics. Accidental entanglements and deaths of wildlife, including birds and marine mammals, can occur. In some regions, lethal shootings, or questionable deterrents such as beanbag bullets and crackers, are used against predators such as seals.

Industry practices can also damage surrounding ecosystems via habitat conversion. The deforestation of the world's mangroves has been caused in large part by shrimp farming. This is due to the shrimp farming's rapid growth and expansion over the last four decades. The industry has relied on a 'boom and bust' model of converting mangrove forests to ponds that are eventually abandoned once destroyed.

Frequent antibiotic use by the aquaculture and the livestock industries to prevent and control diseases contributes to increasing concern that antibiotic resistance will build in farmed animals—and, in turn, we the general public who consume them. The World Health Organization has declared antibiotic resistance—where bacteria are able to survive and continue to cause infection despite antibiotic treatment—as one of the biggest threats to public health, food security and development. Globally, there are approximately 700,000 deaths attributed to antibiotic resistance each year. Left unchecked, we could expect a staggering 10 million deaths per year by 2050.

The overall amount of antibiotics used by the aquaculture industry is difficult to track as few countries effectively regulate, monitor or disclose antibiotic use. Though scarce, some examples do exist. For example, in the Chilean salmon aquaculture industry antibiotics use is extremely high, with over 380,000 kg used by the industry in 2016. For comparison, the Norwegian salmon farming industry's 2016 total antibiotic use was 212 kg. These numbers demonstrate the stark differences in the stringency and effectiveness of the veterinary management and regulations between the two countries. It is not uncommon for government testing programmes to detect banned antibiotics or exceedances of residue limits in imported seafood. Meanwhile, studies have found antibiotic resistant bacteria present in the surrounding environment near shrimp and salmon as well as farmed seafood sampled from everyday marketplaces.

Ways to Improve Seafood Farming

Despite these issues, aquaculture can be conducted in a sustainable manner. Effective government policy and regulations, ecosystem or area-based management and farm site best practices are all crucial in managing the environmental risks aquaculture can pose to our oceans and wild fish. The investment in and adoption of modern technology will also help alleviate environmental impacts. Modern production methods, such as closed containment systems or recirculating aquaculture systems (RAS), provide a 'barrier' as these farms are able to separate farmed fish from wild fish and the marine environment. These are considered lower risk than 'open' systems such as net pens and coastal ponds. Wildlife interactions, pollution, fish escapes and disease transfer risks are eliminated or significantly reduced with closed loop systems. Such systems are also able to control and maintain ideal growing conditions instead of being left to the will of the ocean. Because of this, chemicals and antibiotic use are typically much lower, if used at all. Closed containment systems are becoming more common as consumers seek 'greener' seafood options**.** The additional beauty of this modernized technology is that it can be set up virtually anywhere. For example, in the prairies of Wisconsin, a recirculating aquaponic closed system raises Atlantic salmon and organic greens. Fish waste is broken down with nitrifying bacteria to make nitrate-rich water that nourishes the organic greens. The clean water is recirculated back to the salmon, where the process starts once again. Another advantage of these land-based closed farms is that they can be placed close to markets, saving the need to air freight fresh fish from faraway places and thereby reducing carbon emissions.

Recirculating aquaculture systems (RAS). Salmon. *Credit* Superior Fresh LLC

Algae (namely the macroalgae seaweed) as well as bivalve shellfish such as oysters, scallops, mussels and clams are typically farmed in less intensive methods than finfish or shrimp. Farmers grow seaweed on suspended nets or ropes moored to the sea bottom; sometimes in conjunction with other farmed fish and shellfish in what is called Integrated Multi-Trophic Aquaculture or IMTA. Shellfish farmers place young bivalve on suspended ropes, plastic trays or in mesh bags and allow them to grow naturally. These methods have a low environmental risk as there are no feed inputs, chemicals or antibiotics. As filter feeders, shellfish provide an essential service in maintaining and improving water quality by removing excess nitrogen and other nutrients from the water column. In fact, farmed shellfish have one of the lowest environmental impacts of all animal-based proteins, with its impacts so low that it is comparable, or even better in some cases, to plant-based proteins. Moreover, seaweed is an all over winner for the environment. Its ability to capture and store carbon means seaweed acts as a 'carbon sink' effectively capturing 50% of the carbon trapped in our oceans. This process can also help combat ocean acidification within localized areas as seaweeds help increase pH levels. As discussed in Chap. 2, ocean acidification is a decrease in the pH of the ocean caused by carbon dioxide increases which makes it hard for marine organisms such as bivalves to grow shells. Meanwhile, scientists have found that adding a small amount of seaweed to a cow's diet can help reduce methane emissions by up to 99%. There is growing interest in farming seaweed and shellfish species together in what is known as regenerative aquaculture. It is a win–win. These farms contribute positively to the health of the ocean due to their environmental benefits (improving water quality, capturing carbon and so on) while producing healthy food that sustains people.

Ethical Considerations

In addition to being environmentally responsible, aquaculture should also be conducted in a socially responsible manner. Unfortunately, some farmed seafood industries are notorious for not doing so. Imported farmed shrimp has also been linked to slavery, child labour, hazardous working conditions and other human rights abuses. Land seizures and displacement of local communities for shrimp farm construction have also been documented. In some cases, aquaculture may impede the rights of Indigenous peoples. For example, in British Columbia, Canada, for decades a number of salmon farms have occupied unceded First Nations territories that actively oppose open-net salmon farming. Fortunately, in 2018, a landmark agreement was reached through government-to-government consultations between the Kwikwasut'inuxw Haxwa'mis, 'Namgis and Mamalilikulla First Nations and the province of British Columbia, which resulted in 17 fish farms to be removed from territorial waters by 2023. Demonstrating that, when political will is present, progress on social responsibility issues can be made.

Of increasing concern to seafood consumers are ethical considerations in terms of animal welfare in aquaculture (see Chap. 27). While these concerns are relatively new for fish farming, compared to say pork or poultry farming, they will nevertheless likely change our perception of how we farm marine animals and influence farming practices into the future.

Aquaculture is also framed as a necessity for feeding a growing global population. In 2020, the UN estimated 10% (768 million) of the world's population are undernourished and 2.37 billion are food insecure (i.e. lack year-round access to adequate food). Increasing seafood supply through aquaculture and fishing is expected to contribute to the UN's Sustainable Development Goal of Zero Hunger by 2030. Though increasing supply alone is unlikely to fix the problem. According to FAO, the world produces more than enough food, including fish, to feed everyone on the planet.

So why is there a disconnect between global supply and getting it to those in need? One reason can be found in our bins. Each year, our global food system discards an estimated 35% of seafood. Seafood is 'lost' during farming (i.e. mortalities, escapes), fishing (i.e. bycatch) and processing (i.e. discards, offcuts). At the retail and consumer levels, large amounts of seafood are thrown away as 'waste'. Wealthy nations are among the worst offenders. For example, almost half (47%) of all seafood in the USA is wasted or lost—mostly at the consumer level. The FAO has called on governments to implement policies that reduce food waste by half by 2030.

Another issue is that the type of seafood being prioritized for farming is often inaccessible to those who need it most for reasons such as cost, locality and/or culture. Researchers point to the aquaculture industry's focus of producing high-value seafood, such as farmed salmon, as a global commodity for a few, rather than farming seafood that is nutritional, affordable, culturally diverse and accessible to more. For example, the USD $18 billion salmon farming industry is the fastest-growing farmed seafood commodity by value. Studies also suggest meeting the protein needs of a growing global population requires a shift away from aquaculture that relies on fed species to unfed species (e.g. shellfish and seaweed).

Such a change could yield significant results. For example, one model suggests that if there was enough demand for farmed shellfish, we could globally increase production from the 2.9 billion kg produced each year up to 80.5 billion kg in 2050.

Where Next? And What Can You Do?

Seaweed harvest. *Credit* Cascadia Seaweed Corp

Blanket narratives on aquaculture brand it as compatible with marine conservation, a solution to overfishing, and as a way of sustainably increasing global food production while providing food security and a healthy, nutritious product. Moreover, the narrative aligns with the emerging policy discourse on 'blue growth' within a 'blue economy'—concepts that have been quickly adopted by intergovernmental organizations, such as the UN, the EU, and the World Bank, as well as individual governments and the corporate sector. See Chap. 22 for more on the Blue Economy.

But framing *all* aquaculture with these blanket narratives is misguided. Some farmed seafood options can easily meet these blue growth narratives, while others are fraught with challenges to do so. Unfortunately, industry and government agencies alike have used these narratives to legitimize the further expansion of intensive high-value aquaculture (e.g., salmon) under the guise of 'blue growth'. Instead, government policies and investments should prioritize aquatic food species and production methods that are more inherently compatible and truly aligned with a sustainable 'blue economy': such as bivalves, seaweed and herbivorous finfish. This would help avoid adding further pressure on wild fish for feed. It would also help by contributing more affordable and accessible protein options to our food supply.

Other innovative solutions may be found in the laboratory. The future of seafood is set to include cell-based fish, from tuna to salmon. Repurposing fish feed as human food would also help. It is estimated that 90% of the fish used in reduction fisheries are food-grade and perfectly fit for direct human consumption.

Seafood shoppers can help drive these changes by diversifying our diets beyond farmed salmon and shrimp—whether it be with seaweed, mussels or (in the near future) cell-based seafood. If you must indulge in farmed salmon, ensure it is from a land-based RAS system. And finally, the biggest and easiest action we can take? Avoid throwing any seafood in the bin!

Recommended Reading

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Kelly Roebuck My journey of becoming a conservationist started early. As a young child, I vividly remember spending many hours fascinated by the simple natures within my backyard—cicada shells and lichens were my favourites. Like many children of the 1980s, I was captivated by Sir David Attenborough's The Living Planet. The flora and fauna beyond my backyard and even beyond the shores of my motherland, Australia, mesmerized me. Today I still have the original The Living Planet book, that I would immerse myself in as a 6-year-old, on my bookshelf.

After completing a Bachelor of Applied Science in Conservation Management with honours, I assumed a cushy government position would be ideal—but found out otherwise. Sure, job compensation, stability and other benefits are pros but as a graduate eager to achieve positive environmental gains, I found myself bewildered by the limits of bureaucracy. Shortly after, I took off on an adventure to live and work in Canada. Surrounded by the beauty of the Salish Sea, I had found my home away from home. It is also home to several fierce non-profits and environmental advocates, some of which I have had the honour of working with. For the last 15 years, I have worked on campaigns to improve seafood sustainability, with a focus on aquaculture. My work involves working with actors across the supply chain—from farmers and producers, seafood distributors and suppliers, foodservice providers, restaurant chefs, supermarkets and the consumer—to build support for sustainably produced seafood that will trickle down and incentivize environmental improvements 'on the water' at fish farms. From advocating for salmon farming reforms, analysing aquaculture eco-certifications to implementing farmed seafood policies of major North American retailers—it is a busy and fulfilling job. My journey has taught me that civil society voices, including everyday citizens, local communities and non-government organizations, are vital in helping drive the changes necessary for protecting our living (blue) planet.

Chapter 9
Shark Fishing and Shark Finning

Hollie Booth and Trisha Gupta

Introduction

Sharks belong to an ancient and diverse group of fish called the 'chondrichthyans'. These fish are unique because their skeletons are made of cartilage rather than bone. Over 1100 chondrichthyan species can be found across the globe, spanning marine and freshwater habitats, and in shallow waters and deep seas. The chondrichthyan group also includes rays and the rare and unusual *Chimera*, which are sometimes known as ghost sharks or rabbit fish.

Sharks first evolved over 400 million years ago, and have since diversified into an incredible array of species. These range from the massive whale shark—the world's biggest fish—which is around the size of a school bus, to the tiny dwarf lantern shark, which could fit in the palm of your hand. They include apex predators, such as the powerful great white shark and the speedy mako shark, as well as meso-predators (i.e. mid-ranking predators the middle of the food chain), such as plankton-feeding basking sharks, which are gentle giants of the ocean, and reef-dwelling black tip sharks, which are commonly encountered by scuba divers on tropical reefs. Sharks have also adapted to survive all kinds of habitats, such as the serpent-like frilled sharks and bioluminescent lantern sharks that are found in the deep sea, to the brown-coloured nurse and bamboo sharks that inhabit the sea floor in shallow tropical waters.

With their wide diversity and range of adaptions, sharks play important roles in forming and maintaining functional and productive ocean ecosystems. They also have a long history of interaction with humans and our civilizations. Unfortunately, despite having survived for millennia, they are now highly threatened: it is estimated that 36%

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of sharks and their cartilaginous relatives are threatened with extinction, primarily due to human activities such as fishing and habitat destruction. This chapter provides an overview of the importance of sharks and their relatives for marine ecosystems and people, the threats they face, and some solutions to prevent their extinction.

Ragged tooth shark. *Credit* Steve Benjamin

Why Should We Care About Sharks?

Sharks and their cartilaginous relatives are important for ecosystems and people. The world-famous marine biologist Sylvia Earle once said "sharks are beautiful animals, and if you are lucky enough to see lots of them, that means that you are in a healthy ocean!". Many shark species are apex- or meso-predators (i.e. at the top or middle of the food chains), which means they play important roles in maintaining balance in ocean ecosystems. Declines of shark populations can lead to disproportionate increases in the fish they feed on, which can have cascading and disastrous consequences for ecosystems. For example, declines in coral reef and seagrass habitats have been linked to 'meso-predator release' (a phenomenon in which populations of medium-sized predators rapidly increase after the removal of larger, top carnivores) due to loss of sharks, which have in turn caused the decline of fisheries in those ecosystems.

As well as providing these 'ecosystem services', shark populations also provide direct benefits to humans as a source of fisheries, food, culture and recreation. For example, the global economic value of shark dive tourism is estimated at $US 314 million per year, whilst Indonesia's shark fisheries are valued in excess of $US 125 million in export value alone. Some cultures also worship sharks, and use shark and ray body parts as symbols of power and respect.

However, these important values are diminishing, as overfishing and mismanagement are driving declines of many shark populations throughout the world.

Should We Be Afraid of Sharks?

Contrary to popular belief, sharks pose very little risk to humans. There are only a handful of shark species which are capable of biting humans, and records of shark bites are exceptionally rare. They generally only occur when sharks are harassed, defending their territory or mistake a human for their usual prey species, and even when they do occur, they are usually non-fatal. Remember, sharks do not have hands, so the only way they can investigate something new is by bumping it with their nose or testing it with their teeth. Animals which are more likely to kill humans than sharks include bees, dogs, cows, hippos, deer and horses!

Threats to Sharks

Vulnerable Life Histories

Despite their reputation as fearless apex animals, many shark species are actually more susceptible to human pressures than other fish. This is because they are typically slow-growing, late-maturing and produce few offspring. For example, whilst a swordfish can produce over 4 million eggs multiple times per year, a big eye thresher shark can only produce 2–4 live young (known as ‘pups’) once per year. This means that many shark populations grow very slowly, and when faced with the same level of fishing pressure as other spawning fish, shark populations can become rapidly depleted and take longer to recover. In addition, many shark species have large body sizes and unusual appendages (such as saw-shaped noses and hammer-shaped heads), which can easily become entangled in fishing gears. This combination of sharks’ slow life-histories and high susceptibility to capture in fisheries creates a perfect storm for ‘overfishing’.

Overfishing

Overfishing occurs when the rate at which a population is removed from the ocean by fisheries exceeds the rate at which it can reproduce and recover. Sharks are caught throughout the world’s fisheries, as both the main target species, and as incidental capture (known as bycatch) in fisheries for other commercially-important species such as tuna and prawns.

Targeted capture of sharks occurs when fishers use highly-specialised gears to catch sharks on purpose. This may occur commercially or recreationally. The goal of commercial shark fishing is typically to obtain large quantities of sharks to be sold at market. This can be for a range of commodities, including high-value fins and liver oil from certain species, as well as meat, skin and cartilage. Shark meat and fins are directly consumed as food—shark meat is often sold as a generic seafood product, whilst fins are the main ingredient in shark fin soup—a luxury dish in Chinese culture, which has been served as a token of dignity and respect since the Ming Dynasty. Liver oil and cartilage are most often used as ingredients in health supplements or cosmetics, such as moisturising skin lotions, whilst shark skin may be used to make fashion products, such as belts, bags and shoes. Targeted shark fishing also occurs for recreational purposes, mainly for the 'thrill of the catch', as well as trophies and personal consumption. Recreational fishers usually aim to catch large pelagic sharks, such as mako, thresher and blue sharks. In some cases they are released after capture, though this depends on local regulations.

Sharks in Cosmetics, Handbags and More!

Shark products have a wide range of uses to people, beyond the meat and fins being used for food. Shark and ray skin is used in the manufacture of luxury items like bags, shoes and belts. Their cartilage is used in various medical products, despite limited evidence to show that they have curative properties.

Shark liver oil is a highly valued and commonly traded product. Squalene, which is a component of this oil, is used in a range of cosmetics including lotions, lipsticks and hair conditioners. Squalene is also used as a lubricant, and in certain medicines and vaccines. Demand for their liver oil has led to increased targeting of sharks in some regions, especially deep sea sharks like the gulper shark, potentially putting these species at risk.

Greater awareness and responsible consumer choices of these products can help reduce pressure on sharks and ensure that they are used more sustainably.

Incidental capture of sharks occurs when non-selective fishing gears, such as a large nets or lines, are used to catch other fish, but sharks also become captured or entangled in the process. When this occurs, sharks can usually be kept and commercially-traded, which means fishers and fishing companies have limited incentives to avoid catching them, and may even purposefully retain them as high-value secondary catch. Shark finning is a specific case of shark fishing, whereby the high-value fins are removed and the live shark is thrown back into the ocean. It is particularly cruel and wasteful, as the sharks will suffocate if they cannot use their fins to swim, and become susceptible to predation. Throwing finned sharks alive back into the ocean may occur in both targeted and incidental fisheries, because fishers do not want to take up space on the vessel.

With rapid expansion of fishing pressures throughout the world's oceans in the past 50 years, it is estimated that global oceanic shark populations have declined by more than 70%, and more than one in three shark species are at risk of extinction.

Habitat Loss

Aside from fishing, different human activities can put sharks at risk by damaging the habitats that these species depend on. Many shark species use coastal habitats such as coral reefs, mangroves and seagrass beds, as well as estuaries and rivers. Some species inhabit these regions throughout their lives, like blacktip reef sharks, whilst others come close to the coast to breed and produce their offspring, like scalloped hammerhead sharks. Shark pups also often spend the first few months or years of their lives in these coastal habitats, where they receive abundant food and protection from predators. Development activities along the coast have accelerated with time as the human population grows, damaging these critical habitats and the biodiversity that they support. For example, disappearance of the Ganges shark in India is largely because of the degradation of its habitat.

Management Complexities

The fin of a silky shark being removed after capture. *Credit* Paul Hilton/Greenpeace

Some regulations are already in place across the world to help reduce threats to sharks. Examples include regulations on international trade for more than 40 species under the Convention on the International Trade of Endangered Species, which aims to ensure that international trade in wildlife is sustainable; full protection of some species in some countries, which means they cannot be caught and retained; and 'fins-attached' rules for commercial vessels operating in international waters, which are designed to prevent cruel and wasteful finning practises, and require that sharks are brought back from fishing trips with their fins naturally attached to their body. However, sometimes these regulations are not appropriately implemented because fishers are not incentivised to comply, fisheries are difficult to monitor, and governments lack the capacity and political will.

Whilst banning shark fishing and trade entirely may seem like an easier solution, it is unfortunately not that simple. This is because shark overfishing is characterised by a range of socio-economic drivers and complexities.

Firstly, whilst some sharks are intentionally captured for commercial purposes, many are also captured in small-scale fisheries in the global south, where people are highly reliant on fish and highly vulnerable to food insecurity. In these places, sharks can play a critical role in providing food, nutrition and livelihoods for coastal communities. In other places, the capture, trade and consumption of sharks is driven by strong social norms and cultures. These socio-economic complexities mean that banning shark fishing creates an ethical dilemma.

Preparation of shark meat skewers in Lombok, Indonesia. *Credit* Hollie Booth

Moreover, the vast majority of shark fishing mortality is caused by incidental capture in high-value fisheries for other species. To address this, there is a need to incentivise fishing companies to avoid or release sharks, however it can sometimes be technically challenging to avoid them entirely. For example, some sharks just ‘hang out’ where the other commercially and nutritionally-important fish hang out, which means they are difficult to avoid; and once sharks become entangled in these gears they may already be dead before fishers get a chance to release them.

Finally, lessons from other policies which have sought to ban high-value products have shown that this can increase prices, drive trade underground and remove all means of legitimate monitoring and sustainable management. In parallel, examples of robust science-based management in the USA, Canada and Australia indicate that some shark populations can be sustainably fished—and thus provide benefits to people and ecosystems–provided the fisheries are well-managed. As such, a ‘blanket ban’ approach could be difficult to implement, and have perverse consequences for shark populations and people.

Rather, different policies are needed for different species and contexts, and at different levels of the train.

All About the Fins?

Shark finning and fin trade have often been portrayed as the main threat to shark populations across the world. But how true is this?

Sharks, especially small-sized species, are increasingly targeted and captured for their meat, which is consumed across the globe in various forms. More often than not, sharks are captured incidentally in fishing gear rather than targeted. Even if their fins are sold in these cases, fin trade is not the reason that they were captured. It is important that we look at the larger picture and identify the various drivers of the threats that sharks face, so that we can take appropriate action for their conservation.

Solutions

Fisheries, trade and consumption all need to be managed for sustainability. This includes fisheries which target sharks, as well as other fisheries that capture them incidentally; trade in all shark products; consumption of all seafood products, including shark-derived products like fins, and other seafood products which may indirectly impact sharks like tuna and prawns.

In general, there are four simple steps which can be adopted by/within fisheries, trade and consumers, to reduce impacts on shark populations. These steps are: (1) Refrain from causing negative impacts, (2) Reduce any impacts that are caused, (3) Restore any negative impacts immediately, (4) Renew damaged shark populations and habitat (Table 9.1).

For example, refraining from fishing activities in important habitats can enable shark populations to recover, as has been shown by huge increases in reef shark abundance in Misool Reserve No-Take Zone in Raja Ampat, Indonesia. Importantly, however, any negative socio-economic impacts on local fishers must be accounted for with such actions. This can include marine conservation agreements with local communities, where they are paid for the fishing rights, as in Misool, or compensated for catches foregone by tour operators, as in Shark Reef Marine Reserve in Fiji. Reducing negative impacts of fisheries can be achieved through science-based sustainable management, as per Alaskan skate and Spiny dogfish fisheries in Northern America. In these cases fisheries are permitted but are well-managed within sustainable limits. Restoring negative impacts of fisheries can be achieved through releasing any sharks that are caught in fisheries, such as via the pay-to-release guitarfish project,

Table 9.1 Four steps (refrain, reduce, restore and renew) for shark conservation that can be adopted by/within fisheries, trade and consumers

	FISHERIES	TRADE	CONSUMERS
REFRAIN	Refrain from catching critically endangered species, refrain from fishing in important habitats	Refrain from trading endangered species, where trade threatens their survival in the wild	Refrain from consuming unsustainably-sourced shark products, and from seafood which has a large bycatch footprint
REDUCE	Reduce negative impacts of fishing on sharks by using bycatch reducing technologies, and ensuring any catches are within science-based sustainable limits	Reduce negative impacts of trade on sharks by ensuring any trade that does occur is well monitored and within sustainable limits	Reduce negative impacts of consumption by eating less seafood and choosing locally-sourced sustainably-certified seafood products
RESTORE	Restore the immediate impacts of fisheries, e.g. by releasing any sharks that are captured, or implementing temporary fishing closures so impacted populations can recover	Promote species recovery through trade, e.g. by incentivising good population management	Donate time or money to a local group who are working with fisheries to ensure seafood sustainability
RENEW	Renew shark populations by investing in large marine protected areas, or renewing areas of nursery habitats Charge bycatch levies against commercial fisheries that damage shark populations, to compensate for the damage	Renew shark populations affected by trade by restoring, enhancing and extending critical habitat. Charge trade levies for commercial trading to reinvest in conservation measures	Donate to an international conservation charity working with shark fishers or in marine protected areas for sharks; use your voice to drive social and policy change at scale

which has been implemented for critically endangered species in small-scale fisheries in Southern Brazil during the past decade. Finally, renewing negative impacts could involve revitalising damaged shark habitats and populations, with commercial fishing companies investing money into shark conservation to compensate for past negative impacts (e.g. ‘bycatch levies’).

For trade, refraining from trading endangered slow-growing species can help to prevent damage to populations. Appropriate implementation includes effective law enforcement, and providing alternatives and incentives for fishers and traders—as shown by the ban on manta ray trade in Indonesia in 2014, which was implemented via a combination of enforcement measures against high-level illegal traders (e.g. arrests, confiscations and prosecutions) and providing alternative livelihoods (e.g. new fishing gears and training) for fishers who previously depended on harvesting mantas. Similarly, negative impacts of trade can be reduced through well-managed quotas for species and populations that can withstand commercial trade, such as gummy sharks in Australia.

Seafood consumers can contribute to shark conservation by refraining from purchasing or consuming shark products, such as fins, liver oil or meat. For example, public awareness campaigns have reduced demand for and popularity of shark fin soup in China. Consumers can also reduce their impact on shark populations and other marine biodiversity by choosing sustainable seafood products. The Marine Stewardship Council (MSC) operates globally to certify products from sustainable fisheries, to help incentivise fishing industries to improve their practises as well as guide consumers to make more sustainable choices. Similarly, InSeason Fish produces guides and calendars for sustainable seafood species at a regional level in India. Chapter 10 provides a more in depth review of the sustainable seafood movement.

In Summary

In conclusion, despite their reputation as fearsome predators, we should be more worried that sharks are disappearing from our oceans than about bumping into one in the sea. This is because sharks very rarely harm humans, whilst humans kill an estimated 100 million sharks per year. Moreover, they are important for maintaining healthy ocean ecosystems, and providing benefits to people. The dramatic declines in shark populations that have occurred over the past 50 years could lead to species extinctions and cascading impacts on ecosystems and fisheries. To halt further declines, prevent extinctions, and allow shark populations to recover we need to manage fisheries, control trade, and moderate consumption. Importantly, this includes managing all fisheries, not just those which specifically target sharks, since most sharks are killed as bycatch in non-target fisheries.

What Action Can You Take?

For readers who are interested in what they can do to contribute, they could follow the four R's in their daily lives: (1) Refrain from causing negative impacts on sharks by avoiding seafood products with a large bycatch footprint, (2) Reduce any impacts by only eating sustainably-sourced seafood, (3) Restore any negative impacts immediately, such as by donating time or money to local groups who are working on marine conservation and seafood sustainability, (4) Renew your relationship with sharks and the ocean by supporting international conservation groups, and using your voice to drive social and policy change in your community and country.

Further Reading

Popular Articles

Avoid, minimise or remediate? Shark and ray conservation in an Indian trawl fishery: https://www.iccs.org.uk/blog/avoid-minimise-or-remediate-shark-and-ray-conservation-indian-trawl-fishery
Bycatch levies article in The Conversation: https://theconversation.com/seaspiracy-how-to-make-fishing-more-sustainable-by-tackling-bycatch-new-research-158315
If new international protections are going to save sharks, we must work with shark fishers https://www.iccs.org.uk/blog/if-new-international-protections-are-going-save-sharks-we-must-work-shark-fishers
Predators as Prey: why healthy oceans need sharks: https://oceana.org/sites/default/files/reports/Predators_as_Prey_FINAL_FINAL1.pdf
Sharks and rays worth more alive but to whom: https://www.iccs.org.uk/blog/sharks-and-rays-worth-more-alive-whom

Scientific Papers

Bright spots of sustainable shark fisheries: https://www.sciencedirect.com/science/article/pii/S0960982216314646
Higher Abundance of Marine Predators and Changes in Fishers' Behavior Following Spatial Protection within the World's Biggest Shark Fishery: https://www.frontiersin.org/articles/https://doi.org/10.3389/fmars.2016.00043/full
The Shark Reef Marine Reserve: a marine tourism project in Fiji involving local communities https://www.tandfonline.com/doi/abs/https://doi.org/10.1080/09669580903071987

Other Resources

More about the 4Rs concept (Refrain, Reduce, Restore, Renew). Check out the Conservation Hierarchy: https://www.conservationhierarchy.org/

Get advice on sustainable seafood e.g. from seafood watch: https://www.seafoodwatch.org/

Things more likely to kill you than a shark: https://www.peta.org/features/shark-attack-vs-other-causes-of-death/

Dr. Hollie Booth I am an interdisciplinary conservation scientist from the UK, with more than a decade of experience working on a range of complex conservation issues in challenging contexts. My career has taken me from international wildlife policy in Cambridge, UK; to community-based tourism in Ethiopia; to anti-poaching and protected area management in Tanzania; and eventually to shark and ray conservation in the South East Asia Archipelago. I am a first-generation university student, with a PhD in Interdisciplinary Approaches to Shark and Ray Conservation from the University of Oxford, as well as degree in Natural Sciences and Management Studies from the University of Cambridge and a Masters in Conservation Science from Imperial College London. When I'm not interviewing shark fishers or analysing shark trade data, you can usually find me surfing, running, reading sci-fi books, or at the beach in Bali with my two rescue dogs.

Trisha Gupta I have been fascinated by the ocean and its mysteries from a very young age. Although I grew up in an Indian city that is far away from the coast, I always looked for any excuse to be by the sea and explore its secrets. Combining this with an inclination for science and a passion for nature, I decided to pursue a career in marine biology. Soon after my masters, an internship on fisheries in the west coast of India exposed me to the real world of conservation–where it is not just about protecting marine species but also about the lives of coastal communities interacting with and dependent upon the ocean. My interests then expanded to understanding some of these multidimensional problems and their solutions. I am currently doing a Ph.D. at the University of Oxford on shark and ray fisheries in India. Whilst it can be challenging work, I do get to spend a lot of time in some beautiful areas along India's coastline!

Chapter 10
The Move to Sustainable Seafood

Momo Kochen

Our Needs Determine How We See the World

According to Maslow's theory, humans have five categories of needs: physiological, safety, love, esteem and self-actualisation. These are depicted in a hierarchical pyramid where more fundamental needs such as food and shelter sit at the bottom and more abstract concepts such as self-fulfilment are met as one moves up. Maslow believed that as a lower and more important level of need is met, the next need on the hierarchy becomes the most relevant to the person or community, until they have reached the top and all needs are met.

Given the many differences between small-scale fisherfolk and industrial scale fishing, as well as the spectrum of purchasing behaviours and abilities around the world, Maslow's theory is quite relevant when applied to seafood. You might wonder for example why some honest working fishing communities dump plastic into the ocean, or lack enthusiasm for data collection on their vessels. Why is it not obvious that collecting data can lead to better management, healthier fish stocks and ultimately more secure livelihoods? Or that discarded plastic is a potential health hazard? Quite simply, the priority of many is keeping a roof over their family's head and ensuring an income. These basic needs are not always met in, for example, the often unmanaged fisheries of the Global South, which are estimated to trade over 60% of global seafood in volume. Catching fish, whether sustainable or unsustainable, is a survival approach for many small-scale fishers everywhere. Returning juvenile fish back into the water or spending limited free time on data entry and reporting is often neither a priority nor part of their world view. Of course, there are always fisherfolk the world over, whether rich or poor, whether educated or not who participate and engage in sustainability and the need to maintain balance in the ocean.

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The dynamic of Maslow's theory extends throughout the supply chain, right the way to consumers. In the developed countries of Northern Europe and North America for example, a growing arena of people seeks high-quality fish they can 'feel good about' that comes from a sustainable source and is caught by fisherfolk, treated and paid fairly. These people have likely ticked off the various needs on Maslow's hierarchy.

How do we understand this world of global seafood trade and engage constructively in it? How do we support employment, food security, sustainable extraction and robust management, while at the same time protect the ocean and all that it provides us? It begins with understanding that the ocean means different things to us all. We cannot expect everyone to be able to share the same intention or ability to invest in sustainable seafood, whether producing, trading or purchasing.

Credit Paul Hilton/Greenpeace

The Origins of the Sustainable Seafood Movement

The sustainable seafood movement emerged in the early 1990s in response to growing concern and frustration that the approach to managing and ensuring environmental sustainability was ineffective, showing slow progress or even influenced by powerful interest groups. The main concerns included overfishing, destructive fishing gears and ecosystem degradation. Catch rates were stagnating, and the number of fish stocks reaching 'fully exploited' status or even 'over-exploitation' was increasing. Simultaneously, the human population continued to increase, with a noteworthy growth in average per capita consumption of seafood, nearly doubling from 9.9 kg/person to 17 kg/person between 1961 and 2007.

The movement emerged with a broad objective to raise awareness amongst the general public and to stop the over-exploitation of species considered to be 'doing badly' in our oceans. The main focus was on (1) decreasing demand on highly asked species and (2) decreasing destructive fishing practices. The consumer is the target—the 'agent of societal change'—those capable of 'voting with their wallets'. The movement was built on the assumption that if enough people demanded a sustainable product, then supermarkets, restaurants and the extended supply chains would comply and respectively push producers to change their practices, to 'do the right thing'.

Market-Based Solutions

By targeting the consumer and using the supply chain as the catalyst to drive change, a set of tools, or market-based approaches, emerged. These tools aim to facilitate a transition towards sustainable fisheries and aquaculture production. The tools are many and varied and emerged overtime as the movement grew and matured. Some of these tools have proven worthwhile, others less so. Below sets out the various tools, including some of the merits and downfalls of each:

1. *Communication and Awareness (Campaigns, Academic Research, Media, Publications)*
   This set of approaches communicates the movement, its objectives and methods to the public, sometimes to a very tailored audience, other times more generally. The communication can be both positive and informative, or focused on negative aspects and used as a way of calling out the bad actors. Famous campaigns include the 'Dolphin Safe' campaign from the late 1980s, where canned tuna producers were pushed to ensure that dolphins were no longer caught in their nets while catching tuna. Hundreds of online and printed modes for seafood communication exist, including peer-reviewed publications, social media, articles, campaigns, documentaries and others. Campaign organisations such as Greenpeace developed annually updated international rankings of brands or companies on their sustainability and transparency practices, pushing brands to improve so they can surpass their competitors.

   The good: Pressure from good and bad press nudges many industry players in the right direction, resulting in change.

   The bad: Some campaigns and actions have alienated industry, who rather than engage, shift focus onto markets where sustainable and equitable seafood is not demanded. Moreover, awareness does not necessarily mean a shift in behaviour. Sustainable seafood is often more expensive, which can make it difficult for even the most well-intentioned consumers to make the choice at the seafood counter.

2. *Certification Schemes and Rating Systems*
   Certification schemes emerged across a range of sectors including produce, forestry and mining and now also seafood. Certification typically incorporates four main parties as follows:

   1. The standard holder, which creates and maintains the standard, defining what level of sustainability—ecological or other—needs to be met to obtain the recognition of having achieved the standard, depicted usually by a logo displayed on the product;
   2. Certification bodies, who evaluate the performance of a fishery in meeting that standard and approve the granting of a certificate if the required performance is achieved;
   3. The accreditation body which oversees the impartiality of the certification bodies, as well as their appropriate implementation of the standard process and
   4. The client, typically a fishery, a proportion of a specific fishery, or even a specific supply chain within a fishery.

      Some examples of seafood certification include Marine Stewardship Council for wild capture fisheries and GLOBALGAP for aquaculture.

      Rating systems, though not certifications, are a method used by some well-known institutions including Monterey Bay Aquarium's Seafood Watch and the UK's Marine Conservation Society. These tools rank seafood, usually according to a traffic light system, informing consumers what seafood is good to eat, what should be eaten with caution and what should be avoided.

      The good: The process of improvement to obtain a certification or a higher ranking on a rating system is a worthwhile journey for a fishery, as it gains recognition for proactively wanting to improve its practices. Fisheries and the associated supply chains that engage in the improvement process, or have achieved certification may then benefit from preferential market access.

      The bad: Certification is an expensive process, with the cost typically put on the producer (or consumer), generating niche/expensive certified products inaccessible to a wide consumer market. Moreover, while certification has proliferated across the Global North and larger industrial fisheries, it has not yet had a sizable impact in supply chains involving small-scale fisheries, adding to the exclusiveness of the process and the benefits.

3. *Sustainable Business Partnerships*
   While initially the movement focused on the consumer as the 'agent of change', it became clear overtime that targeting the brands, supermarkets and even the restaurants is more effective in promoting sustainable seafood consumption to a wider market. Partnerships between environmental NGOs and industry formed. Commitments related to sustainability were made, by for example retailers (supermarkets and food service establishments), and new sourcing policies promoted. The retailer's aim is to add story and symbolism to their brand,

some genuinely as a shift towards sustainable practices and sourcing, others for marketing purposes and again others to attract sustainably minded investors.

The good: Working with industry is easier than working against them. By engaging the big retailers towards sustainable sourcing consumer behaviour inadvertently changes, without the effort of having to engage consumers individually.

The bad: Instances have occurred where retailers made commitments towards sustainable sourcing but were forced to backtrack as the required level of sustainable product was not available. Additionally, even with all the right market tools, business dictates that industry needs to make a profit, and companies are pushed to grow. We are therefore faced with a dilemma: while growing the demand for sustainable seafood is important, we have to recognise that there is a limit to how much seafood is available in the ocean and therefore how much the industry can ultimately grow.

Credit Momo Kochen

Is the Sustainable Seafood Movement Showing Results?

Whilst there is ample room for improvement, it is important to reflect on the advancements that have been made, both directly and indirectly linked to the movement:

- It is estimated that close to 80% of current marine fish landings come from stocks that are not overfished.
- The movement enhanced general public and consumer awareness on the basic understanding of environmental degradation, overfishing and of the main principles of sustainability.
- The Marine Stewardship Council (the world's most recognised sustainable seafood certification scheme), in 2020, stated that almost 15% of wild capture fisheries are certified or in assessment, and that over 40,000 products are sold with its label.
- Large global collaborative initiatives have developed. Particularly noteworthy are those where companies have made global and long-term commitments towards the stewardship of our ocean rather than focusing solely on extraction and growth, for example towards the UN Sustainable Development Goals and generally towards shifting business models towards supporting a resilient and sustainable ocean.

However, if we think of the original objective—namely that a more informed and engaged consumer prioritises the purchasing of certified or sustainable products—we see that this is far from the reality. Firstly, while there may be some demand for sustainable seafood, particularly in more developed countries, this is not widespread. Surveys show that more often than not, consumers consider price more important than sustainability. In addition, while the burden of improvement (including a large component of the financial burden) lies with the producers and the source of the seafood, the advantages gained, financial or other, remain predominantly with the retailers. This means the apparent incentives—such as preferential market access—are not necessarily working as envisioned to create change at the source. It is considered that the seafood market has not shifted towards sustainability, but has rather become more diverse by having 'greened' a proportion of it. Other results point towards the movement having built a market for sustainable fish, rather than actually having driven improvements within the fisheries and below the water. To dampen the statistics put forward by the Marine Stewardship Council, we see that there is an imbalance in the certification of the Global North and large industrial fisheries vs the Global South fisheries, which only account for ~8% of the total MSC certified fisheries. Unfortunately, small-scale and artisanal fisheries are the least likely to engage in the certification process, though these fisheries have the best hope for being recognised as sustainable due to the characteristics of their fishing gear, i.e. passive gears catching fewer unwanted species, with low seabed habitat impact. Globally, small-scale fisheries employ 25 times more people and use 25% of the fuel to catch approximately the same amount of fish for human consumption as the large-scale industrial fishing sector. So, can we really say the sustainable seafood movement is building a pathway to success?

The Future of Sustainable Seafood

Increasingly, the movement is becoming aware of just how immense the seafood sector really is. The sector incorporates ~2500 species across trophic levels (from plants at the base of the food chain to top carnivores), artisanal vs industrial extraction, regions that span tropical, temperate and polar waters—both fresh and oceanic and from both aquaculture and wild production systems. The question needs to be asked if they should all be lumped together as a single category—seafood—with approaches and solutions being developed without taking this diversity into account. In answering this question, academics, industry, NGOs and other stakeholders are increasingly moving towards viewing and interacting with their work from a systems approach. This however does make things more complicated, because we begin to realise that sustainable fisheries are not just about good environmental practices and eradicating overfishing and destructive fishing approaches. Many more components need to be included to really achieve long-term improvements and overcome the multiple and varied threats, many of which are described in this book, such as ocean plastics, climate change and human rights abuses and slavery in fishing.

The future is looking towards more holistic approaches, solutions originating from systems thinking and a triple E (equity, environmental, economic) or triple bottom line approach. This means that environmental improvement can no longer be the only focus: economic and social (equity) aspects must be incorporated also.

What does that mean in practice? Here are some simple examples that we all need to be promoting or working towards:

1. Think 'Community Supported Fisheries' and 'decreasing your airmiles'. Local fishers selling their products through short supply chains to local consumers mean less pollution through less air miles, less people handling the seafood and thus less economic dilution and a more socially rewarding transaction for producer and consumer.
2. Think the 'Fair Trade' model. Small-scale seafood producers engaging and agreeing to environmental and social standards and therefore receiving an economic benefit for their effort.
3. Think equity across the supply chain. Rather than the current emphasis on producer and producer countries taking the brunt of responsibility (and cost) for improvements, these need to happen at every node of the supply chain. Social improvements in the production, processing and logistics, environmental improvements at sea, in production and transport, and a more equitable economic sharing of the resources across the chain.

Credit Karlos Manlupig/Greenpeace

How to Get Involved

Thinking back to Maslow's Hierarchy of Needs and how it relates to both producers and consumers, and to the last 25–30 years of the sustainable seafood movement, here is a list of practical everyday things that you can do when it comes to seafood:

- If you are a seafood consumer, evaluate your decision to purchase a specific product on one or more of the following:
  - The position of the fish in the food chain—Fish low in the food chain are typically more plentiful and productive. Unlike top predators, such as tuna and swordfish, or deep sea species, such as orange roughy or Chilean sea bass, which are very slow to reproduce, fish low in the food chain are much more resilient to overfishing. If possible, opt for species such as anchovy, herrings, sardines, mackerel and sprat in your seafood consumption.
  - Ask lots of questions—What is the product's sustainability status?—Is it sustainable in all three aspects: economic, equity and environmental? We cannot always tell, or if we can, we cannot always afford it. Inform yourself as much as possible, and if you can't find out these details, maybe take a pass.

- Think about the food miles that the fish you purchase has accumulated. Where possible consume local fish, thereby also supporting the local economy and fisherfolk.
- Do not allow fish to be wasted by letting it go past its consumption date. Waste nothing!
- Consider eating less seafood: Think about the fish you eat and the journey it has taken. Think about the fisher who caught it on a small vessel at sea and the various rural communities it has passed through on its way to processing. Think about the employees in the processing plant, the transport, maybe between islands and across oceans, the storage and now look at its price. Are you paying enough for the journey of the product and for the risks the fisher has endured? The message here is not that only expensive fish should be consumed, but to be mindful that every fish has a story and a journey. We need to pay adequately for that or we may be supporting a product that includes unfair economic or social aspects within the supply chain. If your position (on Maslow's Hierarchy of Needs) allows it, purchase less in aggregate but more 'well-journeyed' fish where you can verify that journey through traceability, reliable certifications and the attached story, and feel good about it!
- Read, stay informed and inspire others. The world of sustainable seafood is complicated and ever changing. Stay as informed as you can on the movement, how things are developing and what part you can play.

Further Reading

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Momo Kochen I have been lucky enough to spend a large part of my career 'on the ground' supporting small-scale fisheries. My first stint was in Negors Island in the Philippines where I supported an information and education campaign for fisher communities and schools. My journey then brought me to Indonesia, while completing an internship for my masters, where I got involved in a small-scale handline tuna fishery. Initially, I worked with the private sector and eventually co-founded a grassroots NGO called Masyarakat dan Perikanan Indonesia, which is still active and strongly supporting small-scale fisheries improvement programmes today. My work in Indonesia included gaining the world's first Fair Trade certification for a fishery, implementing traceability and data collection systems for transparency and for supporting government data and management—generally, conducting 'fishery improvement' work as a means of supporting the communities to access markets globally. This work has continued, most recently in Chile, Peru and Belize under a systems change NGO, Future of Fish. Initiatives include developing and supporting the growth of domestic markets for sustainable seafood, seafood quality improvement initiatives as a means of ensuring better incomes for fishers and again initiatives with a strong focus on data enhancement and technology for better management and supply chain visibility. Most recently, I have joined the board of a UK-based charity called Sustainable Fisheries and Community Trust, again a group focused on improving the lives of small-scale fishers and the sustainability of the fisheries they rely on.

I am honoured to have worked with amazing people, in amazing places and most importantly amazing fishing communities. I really hope that someday the average small-scale fisher can produce sustainable seafood products and that they can reap the social and economic benefits for doing so!

Part III
Ocean Pollution

Chapter 11
Plastic and the Ocean

Ceri Lewis

Introduction

Perhaps one of the most visible human impacts on the health of the global ocean and its wildlife is the increasing amount of plastic litter contaminating our seas. Plastic pollution has now been found in every part of the world's oceans, from the polar oceans, where it can be found frozen into the sea ice, to the tropics, accumulating on the beaches of remote oceanic islands rich in unique biodiversity such as Henderson Island or the Galapagos Islands. These plastic litter items are not just floating on the sea surface, where they can be transported over vast distances by ocean currents, but will fragment, foul and sink over time to the seabed, even reaching the depths of the abyssal plains. Plastic particles can now be found within the guts of a wide range of marine species across trophic levels from the smallest planktonic animals and other small invertebrates, to higher trophic fish and top predators including sharks and marine mammals, making this an issue of huge societal concern.

How Much Plastic Is in the Ocean?

Almost half of the 400 million tonnes of plastic produced globally each year are for items used just once before being discarded, resulting in a growing burden of plastic waste which can already be identified in the geochemical fossil record for the "Anthropocene" (this refers to the current era in which human activity is the dominant influence on climate and the environment). Without serious action and societal changes in the way in which we use and dispose of plastic, the amount of plastic waste entering the ocean each year is expected to almost triple from an

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estimated 11 million metric tonnes in 2016 to over 29 million metric tonnes by 2040, equivalent to 50 kg of plastic per metre of coastline. The best current estimate of how much plastic is currently floating on the surface waters of the world's oceans is around 5.25 trillion plastic particles with a mass of over 260,000 tonnes. However, these estimates do not take into account particles smaller than 250 μm in size (0.025 mm or about 0.01 inches), or the plastic items that are no longer floating on the surface, since most studies have used sea surface trawls with nets of a mesh size of between 200 and 330 μm to collect this data. One recent study that sampled more widely throughout the top 200 m of the ocean's water column, using techniques that capture smaller particles, estimated that the combined mass of just the three most-littered plastics (polyethylene, polypropylene and polystyrene—all commonly used in single-use plastic items such as water bottles, food packaging and plastic bags) of 32–651 μm in size in the Atlantic Ocean alone is between 11.6 and 21.1 million tonnes. This is ten times higher than the estimates made using the surface trawl data. This number still does not account for the plastic debris that has been transported downwards to the seabed by fouling processes or interactions with marine animals. Some of the highest concentrations of marine plastic pollution reported have been found in the sediments on the bottom of the Mediterranean Sea. Plastic pollution is vast and everywhere.

Turtle caught in discarded fishing gear. *Credit* Marco Caré/Greenpeace

What we refer to as "plastic pollution" is actually a complex mixture of different shapes and sizes of litter items and particles, made from a cocktail of different polymers, monomers and chemical additives. The plastics you can easily see and that are the focus of most beach cleaning activities are the larger items referred to as "macroplastics", which tend to be dominated by single-use plastic items such as drinks bottles and plastic bags, or discarded fishing gear. Following the global COVID-19 pandemic, personal protective equipment (PPE) items such as surgical gloves and face masks began appearing in coastal waters and on beaches as part of this macroplastic litter within just a few months of the pandemic erupting and have now also become common beach litter items.

Abandoned, lost or discarded fishing gear, often known as "ghost gear", is a significant component (~10%) of ocean plastic, with an estimated 640,000 tonnes of ghost gear entering the oceans each year. The North Pacific Subtropical Gyre, an area where floating plastics tend to accumulate due to the ocean currents, was estimated in 2018 to contain 42,000 tonnes of large plastic items (>50 cm in size) of which 86% was fishing nets. This poses a significant risk of entanglement for many marine species, particularly affecting marine vertebrates such as whales, turtles and seabirds. In just one incident in 2018, around 300 turtles were discovered dead entangled in ghost fishing gear in Mexican waters. Plastic entanglement and/or ingestion has now been recorded for tens of thousands of individual animals and at least 558 different species, including all known species of sea turtles, 66% of all species of marine mammals and 50% of all species of seabirds. Seabirds are considered to be particularly susceptible to macroplastics via both entanglement and ingestion. It has been predicted that plastic could be found within the digestive tracts of 99% of all seabird species by 2050 and that 95% of the individuals within these species will have ingested plastic by the same year.

Marine Micro- and Nanoplastics

Larger plastic items in the environment eventually break down due to weathering and sunlight-driven fragmentation processes into millions of smaller plastic particles. Once these particles are less than 5 mm in size, they are known as "microplastics", a term which also covers a heterogeneous group of particles with a range of different sizes, shapes and chemical composition and which accumulate in the marine environment from a wide range of different sources. Microplastics that have fragmented from larger plastic items are known as "secondary microplastics". Primary microplastics, plastics that are directly released into the environment in the form of small particulates, are also a significant component of marine plastic debris. Manufactured microbeads added to personal care products received a lot of early attention, with some products containing thousands of microbeads per gram of product, which might pass through wastewater treatment facilities and enter the environment. Following growing public concerns, microbeads have now mostly been removed from these products. But these microbeads represent a relatively small component of microplastic pollution. Microplastics are often classified by their shape which includes beads, fibres, films and fragments, and their transport and fate in the environment are thought to be related to their size, shape and density. There is no lower limit to the size that plastics can be fragmented into, but usually 0.1 or 1 μm is used as a lower size boundary for use of the term "microplastics". Plastics smaller than this size are referred to as nanoplastics. Very little is known about the presence of nanoplastics in the ocean since their tiny size makes measuring them very challenging.

In addition to the fragmentation of larger plastic, litter items are some perhaps surprising sources of microplastic pollution. Synthetic fibres such as polyester and nylon make up around 60% of our wardrobes. When these clothing items are washed, large numbers of fibres are discharged into wastewater, with a single washing machine load releasing up to 700,000 fibres at a time. Whilst some of these fibres will be retained within wastewater treatment facilities, many others will pass through and reach the environment. Lost fishing gear can also fragment in the environment to produce microfibres. As a result, synthetic fibres are often the most prevalent type of microplastic observed within marine samples. Car tyres, made from a mixture of natural and synthetic (i.e. petroleum based) rubbers, also release wear particles through mechanical abrasion which can be washed into the environment and form another important source of micro- and possibly nanoplastics.

Microplastics were first identified as being ocean pollutants, with early studies focusing on the surface currents of the ocean, particularly the ocean gyres, as the key mechanism for transporting these particles around the world. Now microplastics are being detected in freshwater habitats, soils, organisms, Arctic snow and even the Earth's atmosphere, with talk of a possible "global microplastics cycle", equivalent to the carbon or nitrogen cycle, for moving small plastic particles between environmental compartments (e.g. beaches, organisms, air). A key challenge to understanding the ways in which microplastics move and behave in the marine (and wider) environment is the dynamic nature of these small particles. The size, shape, charge and other properties of microplastic are constantly changing as particles continue to fragment into smaller and smaller particles.

The surface properties of any plastic particle will be altered very quickly once it enters the ocean as it becomes rapidly biofouled by the numerous microorganisms present in seawater. Floating microplastics can also become incorporated into aggregates of decaying organic matter, called "marine snow" due to their fluffy appearance, that stick together and slowly sink to the bottom. This forms a transport mechanism that moves otherwise buoyant plastic particles down to the sea bottom. Marine animals interacting with larger plastic debris can alter the shape and size of this plastic and produce microplastics. For example, sea urchins are important grazers in marine ecosystems, using their sharp "Aristotle's lantern" (teeth like structures) to scrape algae off the surface of rocks. Sea urchins will graze on the surfaces of any large plastic debris items on the seafloor that have been colonised by algae, thereby generating and releasing numerous microplastics. One new key area when considering the ecological interactions of microplastic is the recent discovery of selective binding of secretory molecules called "info-chemicals" that many marine animals use to communicate with each other. For example, a chemical that is released when zooplankton graze on phytoplankton, which then acts to stimulate feeding activity in a range of planktivorous species, can also be produced by some of the microbial communities that can quickly develop on any microplastic surface. It is thought this process makes these microplastics smell like food to any nearby zooplankton and seabirds.

Broken down plastic on a beach (microplastics). *Credit* The 5 Gyres Institute

Microplastic Ingestion by Marine Animals

One of the main concerns about marine microplastic and nanoplastic pollution is that their small size overlaps with the size range of the natural prey for many marine animals. This makes them available for ingestion by a wide range of marine animals with different feeding strategies. The rapid biofouling of microplastics by microbes in seawater may also play a role in their mistaken identity as a food source. Laboratory studies have demonstrated that many marine invertebrate species such as mussels or zooplankton that feed by filtering plankton from the water column will ingest microplastics particles when they are present in the water, being unable to distinguish the plastic particles from their natural food. Microplastics have now been found within the stomachs of over 200 different marine animals collected from the wild from all parts of the global ocean, covering all trophic levels from tiny zooplankton to top predators like sharks and marine mammals.

Microplastics have also been found in the faecal matter of both small (zooplankton) and large marine animals (e.g. seals), suggesting that at least some of any ingested microplastic can pass through the digestive system and eventually be excreted. This further highlights the dynamic nature of microplastics and makes it difficult to calculate how much microplastics might pass through any organism over a given time. Some microplastic can also be retained within the body for significant amounts of time following ingestion. Once plastic particles are small enough to be classified within the nano-size range, they are also small enough to pass across biological barriers, such as the gut lining, and to enter the circulatory systems or even cells, making them more likely to be retained within the animal. Measuring the presence of particles at the nanoscale within tissues is technically challenging; hence, knowledge as to the extent to which this happens in the ocean rather than the laboratory remains limited.

The trophic transfer of microplastics from prey to predator has also been demonstrated using laboratory studies. In one set of experiments, mussels were exposed to microplastics in their surrounding seawater, which they ingested via their filter feeding activity, and were then provided as food to crabs that were in otherwise clean seawater. Microplastics were then found in the guts and on the gills of the crabs that had eaten these mussels. This trophic transfer of microplastics from prey to predator has been shown for seals eating microplastic-contaminated fish and for a number of other food webs. The presence of small numbers of microplastics in the stomachs of top predators such as sharks and dolphins also points to the possibility of trophic transfer occurring in the wild at low levels. Because microplastics can be excreted as well as ingested, it is not yet clear whether microplastics biomagnify up the food web in the same way that other persistent environmental contaminants such as PCBs are.

Biological Impacts of Microplastics

Microplastic ingestion rarely causes mortality, but a range of sub-lethal effects of a microplastic diet have been observed. Studying any health impacts of plastic ingestion in a wild animal in the ocean is confounded by the many other anthropogenic and natural stressors that marine ecosystems are currently experiencing; hence, most of our understanding of the health impacts of microplastic ingestion comes from controlled experiments done in laboratories where the microplastics are deliberately added. A common effect observed in these experiments is a reduction in the amount of natural food consumed by animals when microplastics are present in their diet. Lower feeding rates have been reported for a range of different marine animals including copepods (zooplankton), mussels, worms and crabs. This reduced food intake can then lead to reduced energy levels and has been associated with subsequent reductions in metabolic rate, growth, reproduction and development. Compromised immune functions and inflammation responses have also been observed in mussels and lugworms following microplastic ingestion. Subtle changes in animal behaviour, such as motility, hiding responses and predator–prey interactions, have also been observed following exposure to microplastics for some species. The predatory performance and feeding efficiency of juvenile gobies (*Pomatoschistus microps*) in catching their prey (*Artemia* spp.) was reduced in laboratory bioassays when fish were simultaneously exposed to polyethylene microspheres of a similar size and abundance to their prey. Hermit crabs exposed to polyethylene spheres have also been found to show impaired shell-selection behaviour compared to control crabs.

Plastic products have multiple chemical additives, such as plasticisers, flame retardants, stabilisers and pigments added to improve the material's functionality. The hydrophobic nature of microplastics also means that a vast number of other environmental contaminants also often present in seawater can become attached to the plastic surface. This has led to concerns that microplastics might act as a "trojan horse", transporting contaminants into an animal's tissues at higher concentrations than are present in their surrounding seawater. However, other studies suggest that microplastics might actually act as a sink rather than a source of these chemicals to organisms. This is an important area where research is ongoing. Microbes, including many that are pathogenic (i.e. can cause disease) such as Vibrios can also attach to the microplastic surface. Marine microplastics can carry distinct communities of microbes on their surfaces compared to those in the surrounding seawater, which has been termed the "plastisphere". Hence, another area of concern is that that plastics particles might act as mini floating petri-dishes, moving pathogens around the global ocean. Levels of pathogen-colonised plastic debris have been found to be strongly associated with increased infection rates for corals in the Asian-Pacific region, where the likelihood of disease within corals increases from 4 to 89% when associated with overlying plastic debris. This is a relatively new area of research for which much is currently unknown, but which has potential implications for both animal and human health.

Stomach contents of a dead albatross chick. *Credit* Chris Jordan/Greenpeace

Addressing the Plastic Problem

Tackling plastic pollution will not just help us improve ocean health, but will also contribute to the fight against climate change, support biodiversity and build sustainable livelihoods. In addition to the issues around waste management, plastic production, transport and waste incineration has a carbon footprint. In 2019, the production and incineration of plastic produced more than 850 million metric tonnes of greenhouse gases—equal to the emissions from 189 five-hundred-megawatt coal power plants. If our trajectories of plastic use continue as normal, by 2050, the greenhouse gas emissions from plastic production could reach over 56 gigatonnes, which would be 10–13% of the entire remaining carbon budget to stay below 1.5 °C warming. Hence, addressing the ocean plastic pollution crisis by reducing the global production and use of plastics is not just about reducing waste but will also help towards meeting "net zero" targets.

Unfortunately, the global COVID-19 pandemic has resulted in significant increases in our use of single-use, disposable plastic products such as personal protective equipment (PPE), medical products and food and drink packaging. One study estimated that around 3.4 billion single-use face masks were being discarded globally each day during the height of the pandemic. Perceptions that plastic, particularly single-use items, are more hygienic than alternatives have also shifted consumer choices. There is now growing evidence that the pandemic has resulted in a greater environmental burden of plastic waste and lower governance and enforcement of mitigation measures, potentially reversing much of the progress made prior to the pandemic to tackle the global plastic pollution crisis.

Clean-up activities can reduce localised levels of plastic pollution short term and have positive environmental awareness and mental health benefits for those involved. But by far the best approach is to reduce this issue at sources, by reducing the amount of plastic that enters the environment in the first place. A systems approach is required that combines the principles of a circular economy with reduction and replacement of plastic materials, greener by design technologies and better waste management. Eliminating waste and encouraging the continual use of resources by reusing, redesigning, and recycling is a societal challenge, but individual actions also matter. We can all make small changes in our daily lives to reduce our use of single-use plastics.

Suggested Reading

Breaking the Plastic Wave: A comprehensive assessment of pathways towards stopping ocean plastic pollution (2020). Pew Charitable Trusts and SytemmIQ.

The impacts of debris on marine life. Gall, SC and Thompson, RC (2015) Marine Pollution Bulletin 92 (1–2) pp. 170–179.

United Nations Environment Programme. Neglected: Environmental Justice Impacts of Marine Litter and Plastic Pollution. (2021).

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My research focuses on the impacts of global changes, such as pollution and ocean acidification, on marine invertebrates, the smaller marine animals that make up the bottom of the marine food web. I have been fascinated by these small, wondrous animals since my first rock pooling trip as a small child. I wanted to understand how their interaction with their environment has led to so many different life strategies, but soon realised that you can’t study these animals now without taking into account the human-induced changes happening to the ocean in which they live. I am now part of the marine plastics research team at the University of Exeter, and in 2020, we were awarded the Queen’s Anniversary prize for our research into the biological effects of marine microplastics. I have led research expeditions to determine the extent of marine microplastic pollution in a number of remote locations including the Galapagos, the Arctic and the Azores. I am also very active in public and educational outreach, teaming up with an educational charity to get my research findings fed into UK and international schools, and I regularly contribute to government policy consultations and was a scientific advisor to the BBC Series Blue Planet 2 and the documentary “Drowning in Plastic”.

Chapter 12
Shipping and the Ocean

Lucy Gilliam

Introduction

Shipping is an age-old industry that underpins our increasingly globalised economy, with 80% of world trade carried by ships.

The world fleet comprises cargo-carrying ships (dry bulkers, containerships, Ro-Ro ships and tankers), passenger ships (cruise ships and ferries) and fishing vessels. There are some 62,100 commercial merchant vessels sailing the world's oceans today, many of which cross borders or traverse international waters. Ships often operate away from the scrutiny of authorities, and because they are largely out of sight, they have historically been subject to relatively lax environmental, social and labour rules and regulations as compared to operations that happen on land.

For example, the shipping industry today mostly burns forms of heavy fuel oil (HFO) which when burnt releases cancerous toxic substances at far higher rates than we allow from land-based industry or other transport modes. Heavy fuel oil (HFO) is also toxic to humans and wildlife and highly polluting to the environment if accidentally spilt.

This chapter explores some of the ways in which shipping impacts the ocean and planet.

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Credit Cyprien Hauser

Shipping in the COVID Era

Over the period of the global pandemic (2020–21), a range of shipping events brought the environmental challenges from shipping into focus. The COVID crisis led to a rapid increase in demand for shipping and, therefore, overloaded vessels. Simultaneously, the spread of the pandemic created challenges for maritime workers who faced restrictions in crew changeover and port entry. Disruption in global maritime supply chains followed as a consequence as well as a rapid rise in the prices paid for container shipping, with record multibillion dollar profits for the major shipping companies. This prompted conversations to consider if supply chains need to be shortened for resilience, more humane conditions for seafarers to be put in place and a fairer price for shipping where polluters pay for their pollution.

Container ships have been increasing in size for decades in order to carry more containers on each voyage. Bigger ships are more efficient per tonne cargo in terms of fuel and emissions, but this comes at a price. These megaships are increasingly difficult to navigate particularly in narrow canals or waterways where the clearance between ship hulls and waterway floors has become smaller, leaving less room for error and increasing the possibility of grounding. Infrastructure is also struggling to keep up with the growth in size of ships.

Extreme weather as a result of climate change and overloaded vessels, with containers loaded higher than ever before, has led to many more container losses in 2020–21 than in the previous 7 years.

Recent Incidents

- Containership ONE Apus alone lost almost 2000 containers, of which 40 contained dangerous goods, when it sailed into a storm en route to the USA in December 2020. Prior to 2020, the average was 1390 a year according to the World Shipping Council.
- In July 2020, the grounding of bulk carrier Wakashio on the reefs of Mauritius spilled more than 1000 tonnes of heavy fuel oil. The oil spill has devastated the local community, the fishers and tour operators. Weak and obscure regulations mean any compensation is unlikely to ever cover the full costs of clean-up and leave the aftermath to be managed by the local community.
- In March 2021, the Ever Given, one of the world's largest container ships wedged in the Suez canal and blocked the world's most concentrated shipping route, (which carries 12% of global trade) for more than a week at a cost of billions of US dollars a day.
- A few months later, container ship X-Press Pearl caught fire off the coast of Sri Lanka, spilling oil, toxic waste pollution and cargo along the coastline. The ship was eventually scuttled in shallow waters off the coast while still leaking fuel oil and toxic chemicals from the dangerous cargo it was carrying as well as continuing to spill tonnes of tiny plastic pellets. Prior to catching fire, the ship had requested to offload the dangerous leaking cargo but was denied entry by two separate ports, endangering life of the seafarers on board as well as the environment.

Major shipping disasters often cause long-lasting damage to wildlife, local communities and for example fishers who lose their livelihood and local food security for years to come.

These recent crises demonstrate that the current regulations of shipping are not sufficient to address pollution or redress the balance after. Poor environmental and social performance go hand in hand, in part due to the Flag of Convenience (FoC) system. This system enables shipping companies to shop around for the flag with lowest social and environmental regulations, low or zero corporate tax and complete flexibility over crew recruitment. Flags of Convenience fuel a race to the bottom on social, environmental and safety standards, ultimately making disasters more likely (see Chap. 7 on Fish Crimes).

How Is Pollution from Shipping Regulated?

The global rules and regulations for shipping are determined principally by the International Maritime Organisation (IMO), a United Nations body based in London. The main international convention covering the prevention of pollution of the marine environment by ships from operational or accidental causes is MARPOL which was adopted in 1978 as a response to a series of devastating oil spills and tanker accidents.

Air Pollution

Satellite tracking of ships shows that most shipping is operating within 90 km or less from coastlines. This proximity to land combined with prevailing winds means ships make significant contributions to air pollution. Most ships currently burn the cheap untaxed "bottom of the barrel" heavy fuel oil (HFO), which is a thick tar-like waste from the oil refining process. HFO creates several types of air pollutants as by-products including carbon dioxide (CO_2), nitrogen oxides (NO_x), sulphur oxides (SO_x), black carbon and particulate matter. Global shipping accounts for 8% of global emissions of sulphur dioxide emissions (SO_2), which is highly acidic when mixed with water making shipping a major contributor towards acid rain. Sulphur oxides, black carbon and heavy particulate matter from NO_x can cause serious lung diseases, especially among young children. Particulate matter emissions from maritime shipping lead to 400,000 early deaths worldwide a year and cost over $50 billion a year in global health costs.

These emissions from shipping have been steadily increasing over the last thirty years with the growth in ship traffic. Several options exist to reduce air pollution from shipping including measures that are already standard practice for land transport. Examples include cleaner low-sulphur fuels with diesel particulate filters and use of Selective Catalytic Reduction (SCR) technology to reduce nitrogen pollution. In ports, ships can connect to electrical shore power or run on renewable fuels like hydrogen or energy stored in batteries. Regulations are needed to drive the uptake of cleaner technologies and can include designating waters as emission control areas (ECA) and ports as zero-emission areas.

Sulphur Emissions

On 1 January 2020, a new global limit on the sulphur content in the fuel oil used on-board ships came into force which limits the sulphur content in fuel while operating outside designated emission control areas to 0.5%. Ships can either comply by using cleaner low-sulphur fuel or using scrubbers (exhaust gas cleaning systems) to remove sulphur, which unfortunately has other adverse effects on the marine environment. These systems also capture additional pollutants like persistent organic pollutants (POPs), polyaromatic hydrocarbons (PAHs) and heavy metals, which are then discharged into the water surrounding the ship. For every tonne of fuel burned, ships using open-loop scrubbers (a system designed to lower the sulphur content of emissions) discharge approximately 45 tonnes of warm, acidic and contaminated wash water, containing known carcinogens into the ocean. This cocktail of contaminants includes polycyclic aromatic hydrocarbons (PAHs) and heavy metals and can bioaccumulate in sediments with hazardous consequences for wildlife and the food web. Heavy metal pollution has been linked to damage to the central nervous system in humans and animals. PAHs have been blamed for skin, lung, bladder, liver and stomach cancers and are known to disrupt the endocrine (hormone) systems of organisms even at relatively low concentrations. Scrubber waste discharge is warmer and more acidic than the surrounding water, and increasing acidity makes toxic heavy metals more bioavailable to wildlife. Several countries have already restricted the discharge of scrubber waste in ports and coastal waters. Using scrubbers slows down efforts to transition to cleaner fuels while creating new marine pollution.

The highest standards of sulphur emissions from ships are found in Europe and North American emission control areas (ECAs), which include the US Caribbean. In the ECAs, sulphur emissions are limited to 0.1%. Yet this limit is still 100 times higher than the fuel standard for road transport in the EU.

Greenhouse Gas Emissions

Shipping emits over 1 billion tonnes of carbon dioxide equivalent (CO_2e) per year, which is about 3% of global annual CO_2 emissions. CO_2, black carbon and methane are the main contributors to global warming from shipping.

In 2018, the IMO agreed on a draft greenhouse gas strategy requiring international shipping to reduce emissions by at least 50% by 2050 compared to 2008 while pursuing efforts towards phasing them out as soon as possible. Unfortunately, this is nowhere near ambitious enough, and efforts are ongoing to push parties to the IMO to cut emissions faster. The Paris Climate Agreement requires parties to reduce all emissions across the entire economy. Shipping, like other sectors of the global economy, would need to cut emissions in half by 2030 and completely eliminate emissions by 2050 at the very latest to make a fair contribution towards keeping climate heating below 1.5 °C. The EU is further taking on the challenge of reducing shipping emissions by proposing to include shipping in the EU Green Deal, a package of regulatory measures to tackle climate change.

There are several technology options to decarbonise shipping. First and foremost, there is significant potential for operating ships more efficiently so they burn less fuel and therefore produce less climate heating emissions. These include slow-steaming, more efficient ship designs, and the use of renewable energy directly for propulsion with wind systems. Reducing the speed of the shipping fleet would not just reduce shipping's climate impact but would also reduce air pollution, underwater noise and fatal collisions between, for example, whales and ships. The remaining fuel demand must switch from fossil-based fuels to renewable energy carriers, such as battery electric propulsion and hydrogen-based fuels.

Black Carbon Particulate Matter

Black carbon is a tiny black particle found in smoke from ship exhausts, which not only contributes to heart and lung disease but is also damaging to the environment and is a powerful short-lived climate pollutant. Per unit of mass, black carbon has a warming impact on climate that is 460–1500 times stronger than CO_2 by converting incoming solar radiation to heat, and when falling on ice or snow, accelerating melting. Despite over a decade of negotiations at the International Maritime Organisation, there are no binding national or international regulations that limit black carbon emissions from ships. Black carbon accounts for 21% of CO_2-equivalent emissions from ships, making it the second most important contributor to climate impacts after carbon dioxide. Emissions of black carbon from shipping are particularly concerning in the Arctic, given that the rapid melting of sea ice is increasing the access of ships through the Northern sea routes between Europe and China. The Clean Arctic Alliance is a network of NGOs calling for the urgent regulation of black carbon emissions from shipping, particularly in the Arctic.

Protest outside the IMO. *Credit* Henry Kenyon/Extinction Rebellion

Case Study Cruise Ship Air Pollution

There are 323 cruise ships in the world today which accounts for less than 1% of ships worldwide. However, due to their size and number of passengers, cruise ships are responsible for significant environmental impact. Over the years, they have gained in popularity, offering at sea experiences on increasingly larger vessels, often housing as many as several thousands tourists for extended periods of time. These floating villages visit some of the most remote places on earth, including the polar regions and remote islands, with limited infrastructure. Cruise liners can leave a wake of destruction in their path, including pollution, disruption to wildlife and the destruction of sometimes rare and unique coastal habitat in order to dock these behemoth vessels. Given the size and nature of cruise liners, for example operating in international waters, recruiting crews from multiple nationalities and remaining largely out of sight of law enforcement, the cruise line industry has been implicated in a number of controversies including human rights abuses and unlawful or unregulated discharges of toxic pollution to the ocean.

Looking specifically at sulphur emissions, the cruise vessels operated by just one company, Carnival Corporation, emitted ten times more SO_2 in European seas in 2017 than all of Europe's 260 million plus passenger cars. Even in sulphur emission control areas, where the strictest rules for fuel sulphur content apply, air pollution from cruise ships remains of great concern. In Denmark, for example, whose coasts are entirely within SECAs, cruise ships emitted 18 times more sulphur oxides (SO_x) in 2017 than all the country's 2.5 million passenger vehicles in a year. This is a reflection of both the effectiveness of the fuel quality directive for road transport fuels and the failure to implement equivalent standards for the shipping industry. Sulphur emissions from shipping will remain high compared to the passenger car fleet even with the introduction of the global 2020 marine sulphur cap. For the cruise sector, the outbreak and spread of COVID on board led to a worldwide pause on cruising, leaving cruise ships floundering outside ports on anchor waiting for restrictions to lift. This brought welcome respite for port communities that had been mounting resistance to cruise ships due to their considerable contribution to air and water pollution, as well as concerns about the impact of mass tourism on local culture.

Water Pollution

Sewage Waste from Shipping (Blackwater and Greywater)

Sewage waste includes blackwater and greywater and poses a serious risk to the aquatic environment. The amount produced by a ship depends on the number of crewmembers or passengers and the type of ship. Blackwater is wastewater from toilets and medical facilities and risks human health by contaminating seafood and water ingested by surfers and swimmers. In addition, blackwater contains nitrogen and phosphorus, which can lead to excess algal growth resulting in oxygen-poor water, which in turn can suffocate fish and other aquatic life. Greywater is wastewater from sinks, baths, showers, laundry and galleys and can contain a cocktail of harmful contaminants including detergents, soaps, sunscreen, faecal bacteria, among many other things. A large cruise ship can produce more than 500,000 L of blackwater per week.

The wastewater discharge rules for shipping are considered out of date and full of loopholes that render them ineffective, leading to environmental pollution. Currently, a ship can discharge blackwater directly into the water beyond 12 nautical miles from shore, even if that area is a designated environmentally sensitive area. Untreated greywater can legally be discharged almost anywhere, including while a ship is docked in a port near towns and beaches.

Plastic Pollution from Shipping

As discussed in Chap. 11, plastic in all its form poses many risks to the marine environment and contributes to the spread of invasive species, dangerous pathogens, as well as toxicants such as polychlorinated biphenyls (PCBs), organochlorines, polycyclic aromatic hydrocarbons (PAHs) and DDTs present in the water.

Much of the plastic found on beaches or floating in the ocean originates from activities at sea—primarily from fishing, shipping, offshore industries and tourism. For example, a recent study found that 46% of the 79 thousand tonnes of ocean plastic in the Great Pacific are made up of fishing nets, some as large as football fields. Another study found that a likely source of plastic washed up on a remote island in the South Atlantic was from merchant shipping. Indeed ships have long been a major source of ocean plastic due to the maritime tradition of dumping garbage at sea. MARPOL Annex V rules on garbage disposal came into force in 1988 prohibiting the disposal of all garbage into the sea from all vessels (including fishing vessels and pleasure yachts). However, plastic pollution is not just the result of accidental garbage waste, it is also a result of lost fishing gear or waste from shipping. Plastic pellets, carried as cargo, are frequently spilt with estimates of around 230,000 tonnes annually. To address global concerns about marine pollution, the IMO is currently developing an action plan to address marine plastic from ships. Proposals include collecting data to establish the sources of plastic and measures to reduce marine plastic litter from ships: for example compulsory reporting of containers or fishing gear lost at sea, making marking of fishing gear mandatory, improving port waste facilities, building awareness with the public, maritime and fishing workers, while also strengthening international cooperation between UN bodies.

Ballast Water

Ballast water is fresh or saltwater held in the ballast tanks and cargo holds of ships and is used as a way to manage the weight of the ship. Discharge of ballast water is a major pathway for the introduction of non-indigenous marine species. Examples of invasive species that cause harm include the carpet sea squirt, which forms a physical barrier on the seafloor to native grazing fish, the comb jelly, a voracious predator and cholera (Vibrio cholera), a threat to humans if ingested via drinking water or seafood. Ballast water is regulated by the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 (BWM Convention), and entered into force globally on 8 September 2017.

Underwater Noise

As discussed in Chap. 14, a less visible but devastating form of pollution caused by shipping and other maritime human activities is underwater noise pollution.

Shipbreaking

The environmental impact of a ship does not end when it reaches the end of its operational life. Decommissioned ships are full of toxic materials as well as economically important materials. Despite strict regulations on ship recycling in the EU for example, most shipping companies exploit flag state rules to enable ships to be dismantled cheaply and dangerously. This often happens by hand on the beaches of less well-developed countries, including Southeast Asia, creating serious environmental pollution and hazardous working conditions, which leads to frequent injury and loss of life.

Abandoned ship on the beach in Mauritania. *Credit* Farah Obaidullah

Further Action

The environmental impact of shipping is growing rapidly, driven by the increasing number and size of ships plying the oceans to fuel our increasing demand for consumer goods. We live on a finite planet, and the shipping industry cannot absolve responsibility by arguing that it is simply responding to market forces. As we move to replace fossil fuels with renewable sources of energy and shift to circular economic models, then what we ship, where we ship and how we ship will change. There are arguments to be made that in some particularly vulnerable marine environments, shipping activities should be prohibited entirely to protect biodiversity.

Awareness of the environmental impacts of shipping has historically been low. However recently, an increasing number of civil society NGOs have engaged in campaigns to clean up shipping, and new grassroots movements have sprung up to resist further growth in the sector and protect coastal communities. The largest grassroots movements on shipping are as follows: Global Cruise Actíon Network and the Clean Up Carnival campaign group who are both protesting the many negative environmental and cultural impacts of cruise ships. Recently, a group called Ocean

Rebellion rose out of the global Extinction Rebellion climate movement to raise awareness of shipping pollution.

This is a conversation that is urgently needed not least because we have to ensure that as we recover from the global pandemic, we also tackle the interlinked climate and biodiversity crisis. The global shipping system has been facilitated to grow by hidden public subsidies to build ever bigger ports and ever bigger ships, while simultaneously leaving the industry virtually untaxed and weakly regulated—all in the name of efficiency and promotion of global trade.

We have to turn this ship around. This requires greater awareness of all shipping's environmental problems combined with robust enforceable systemic approaches to governance. Shipping underpins a global system of trade that must change if we are to meet our environmental and social goals. It is high time we evolve the system.

Things Readers Can Do

- Buy local, repair and reuse and call for companies to also tackle their supply chain emissions (for example the *ship it zero* campaign—https://shipitzero.org/). Overall reductions in consumption could result in reduced demand for maritime transport.
- Avoid mass cruise tourism or ask cruise or ferry companies to clean up their emissions and apply high zero pollution standards.
- Lobby for shore power and clean berth standards so that ships clean up their emissions in port.
- Choose products from companies that are shipping their products in a zero-emission way, or ask your favourite companies to reduce their sea transport emissions and or ship with companies that are operating their ships at slow speeds.
- Make sure shipping emissions are included in national climate targets and policies are developed to bring emissions down in line with the Paris Agreement climate goals.

Further Reading

Boom in ships that fly 'fake' flags and trash the environment: https://www.nature.com/articles/d41586-021-01391-3

Cruise Air pollution report: Transport & Environment (2017) One Corporation to Pollute Them All - Luxury cruise air emissions in Europe. See https://www.transportenvironment.org/sites/te/files/publications/One%20Corporation%20to%20Pollute%20Them%20All_English.pdf

Decarbonising shipping: Transport & Environment (2018) How to decarbonise shipping See: https://www.transportenvironment.org/publications/how-decarbonise-shipping

Global scrubber washwater discharges under IMO's 2020 fuel sulfur limit: https://theicct.org/publications/global-scrubber-discharges-Apr2021

IMO 4th GHG study: https://www.imo.org/en/OurWork/Environment/Pages/Fourth-IMO-Greenhouse-Gas-Study-2020.aspx

The multi-issue mitigation potential of reducing ship speeds: https://seas-at-risk.org/wp-content/uploads/2021/03/2019.6.11.-Mitigation-ship-speeds.pdf

Key Organisations Working to Tackle Shipping Pollution

Clean Arctic Alliance: www.hfofreearctic.org
Clean Shipping Coalition: www.cleanshippingcoalition.org
International Council for Clean Transportation (ICCT) www.theicct.org
NGO shipbreaking platform: https://shipbreakingplatform.org/
Pacific environment.org: www.pacificenvironment.org
Seas at Risk: https://seas-at-risk.org/18-shipping.html
Stand.earth: https://www.stand.earth/protect-arctic/clean-ship-fuel
Transport and Environment: https://www.transportenvironment.org/what-we-do/shipping-and-environment

Dr. Lucy Gilliam My lifelong passion is tackling climate and marine pollution. I grew up sailing, spending all my spare time on the water. Now, whenever I get the chance, you will find me on my paddleboard or kayaking with my son. I currently work on Shipping Policy for the Brussels-based NGO, Seas at Risk, advocating for stronger regulations to tackle the environmental impact of shipping. Prior to Seas at Risk, I worked as a campaigner for Transport and Environment. My interest in shipping was sparked when I joined a voyage sailing across the Atlantic emission-free on a sailing cargo vessel, which led me to co-found a sail trading company. During my time sailing cargo across the Atlantic, I became aware of the global ocean plastic problem. As a result, I co-founded eXXpedition, a pioneering all-female sailing voyage and scientific research mission studying ocean plastic & toxics and helping people use their skills to solve it. I have sailed on several eXXpedition research missions including the maiden voyage across the Atlantic in 2014 where I was shocked to discover, during the first plastic trawls, there were more plastic fragments in the net than organisms despite being several hundred miles from civilisation! I have a Degree in Biology and Ph.D. in Molecular Microbiology as well as a Diploma in Commercial Coastal Seafaring from Enkhuizen Nautical College. My career has spanned academia, government, grassroots activism and supranational policymaking.

Chapter 13
Oil Spills

Sian Prior

This chapter focuses on oil spills and international efforts to mitigate the impact on the oceans, communities, and wildlife.

What Is Oil?

Oil is formed from the prehistoric remains of animals and plants that have died and been compressed and heated. This is crude oil, and it has to be extracted from the ground whether on land or in the ocean. It is refined to form fuels, lubricants, plastics, rubber, industrial chemicals, and a wide range of other products. The refinery process divides crude oil into lighter components such as natural gases, kerosene, and light diesel oils; medium grade oils; and residual or heavy oils, which are left at the end of the refining process.

What Is an Oil Spill?

Oil that enters the environment through human causes can be considered a spill, including through accidents and intentional releases. In the ocean, oil spills can occur through shipping accidents; leaks from pipelines, boats, and coastal or offshore development; washings or discharges from ships' tanks and lubricating oils; run-off

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from land via rivers and jettisoned aircraft fuel. Spills also result from deliberate sabotage of oil wells and pipelines. Large spills generally result from a terrible accident, and people are often also killed in such incidents. The impact of a spill depends on the type of oil spilled, the environment into which it is spilt, and the weather conditions.

Scene of the oil spill in the waters around Mauritius after Japanese bulk carrier, MV Wakashio, ran aground on 25 July 2020. *Credit* Jean Garrett/Greenpeace

Impacts of Oil Spills on Marine Life

Oil has a toxic impact on wildlife. The lighter, more toxic components of oils evaporate and impact air-breathing animals like seabirds, turtles, marine mammals, and even people responding to the spill. Oil smothers and damages habitats and sticks to animal's feathers, fur, or skin, especially seabirds, seals, and marine otters. While attempting to remove the oil from their bodies, the animals swallow it, and the toxins interfere with the animal's ability to feed, breathe, breed, and survive.

In the water, some oil spreads out and breaks down relatively quickly, in particular where clean-up chemicals are used. However, the dispersed and broken down oil is often consumed by marine wildlife, particularly fishes. The oil can then accumulate in the food chain, as the fish are in turn eaten by seabirds and marine mammals. Sometimes, oil mixed with sand and sediments may reappear many months or years after the spill and can still stick to the feathers, fur, or skin of animals that come into contact with it.

What Causes Oil Spills in the Ocean?

Shipping Accidents

Ships carrying or fuelled by oil can cause a spill if involved in an accident. Accidents might be collisions between ships or between a ship and a structure such as breakwaters, piers, rocks, or icebergs. Ships might also spill oil when they run aground on a shallow reef or suffer a malfunction.

Chronic Discharges

Every year over 300,000 tonnes of oil are released into the ocean through the routine operation of ships. This oil comes from leakage from the stern tubes which link the ship's engine and the propeller; lubricating oils used on deck and underwater; and washing out of cargo holds that deliver oil. These sources of oil are allowed by law, but illegal discharges often occur at the same time. In the late 1990s, 300,000 birds were dying every year off the Newfoundland coast because of chronic oil discharges. Lubricants which biodegrade are less toxic than lubricating oils but are not widely used.

Contaminated Water

Offshore oil and gas installations release oil through "produced water" and "displacement water", which is water that is contaminated with oil, and by digging up and discarding muds and rocks that contain oil, known as "cuttings". Between 2009 and 2017, in the Northeast Atlantic, over 40,000 tonnes of oil were discharged by offshore oil and gas installations, including nearly 2000 tonnes of accidentally spilled oil. In recent years, oil discharged in drilling fluid and cuttings has increased, according to annual reports.

Oil Additives

Chemicals are often added to oil products, such as lubricant chemicals added to fuel oils to help improve engine performance. These additives are also a threat to wildlife. In 2013, in two different incidents, more than 4000 birds including guillemots, puffins, razorbills, and gannets washed up on beaches on the south coast of England covered in a sticky substance. The substance was an additive sometimes added to oils in ships' engines, which was being flushed into the sea during the cleaning of ships tanks. At that time, the discharge was allowed by law, but subsequent action by the International Maritime Organization (IMO), the United Nations body responsible for regulating international shipping, banned the discharge at sea and required any residues to be disposed of while ships are in port.

How Else Does Oil End Up in the Ocean?

Natural seeps, where oil leaks from the underlying seafloor sediments, are the largest source of oil in the ocean. Directly at the seep, the oil is toxic to marine wildlife particularly animals living on the seabed. Ecosystems close to oil seeps are adapted to the slow release of oil over long time periods, and some bacteria can even use parts of the oil as an energy source. The oil from a seep can however spread and affect wildlife, particularly seabirds, from further afield. A Californian study found natural seeps off the coast oil around 1000 seabirds each year.

Impacts of Oil Spills

In general, the bigger the oil spill, the larger the environmental and social impact is. However, even small spills can have a major impact. For example, in 2000 the *MV Treasure* spilled 400 tonnes of fuel oil following structural damage during bad weather off the coast of South Africa. The spill resulted in the temporary closure of South Africa's ports and had a major impact on the penguin colonies because it happened during their breeding season. The biggest marine oil spill occurred in 2010—the Deepwater Horizon oil spill—where the offshore drilling rig suffered a malfunction, explosion, and fire, resulting in the death of eleven people. The well gushed crude oil into the Gulf of Mexico for 87 days before it was capped and stopped. Much of the oil was released at depth and damaged deep-water marine habitats. Around 572 miles of coastline were affected, along with thousands of seabirds and marine wildlife including dolphins, turtles, and fishes. Four years after the spill, a study on the very young life stages of fishes, such as tuna, indicated biological defects after exposure to the oil (see Box 1).

Oil spills also affect local communities dependent on coastal and marine resources. Following an oil spill, it is usual for fisheries in the area to close until authorities can be confident that there is no risk to the public from the consumption of fish and shellfish. Closures might last a few weeks, but in some cases fisheries have been closed for many months following a spill. Other industries such as tourism and marine sports can also be restricted or reduced following spills, with impacts on local economies and loss of revenue lasting for months or even years.

See Table 13.1 for examples of oil spills from oil installations, oil fields and ships, and a range of environmental and social impacts. For inspiration from those taking action to reduce the impacts from oil spills, see Chap. 32 on Inspiring Voices, and the incredible achievements of Marilyn Slett and the Heiltsuk community.

Table 13.1 Impacts of a selection of oil spills from oil fields, offshore installations, and ships (n.b. these examples are illustrative of impacts and not intended to be comprehensive)

Name and installation or vessel type	Year	Location	Size of spill	Social, environmental, and economic impacts
Oil wells and pipelines	1991	Gulf of Kuwait	Estimated between 270,000 and 820,000 tonnes crude oil	• Sabotage of wells and pipelines • Oiled area covered more than 4000 km^2
Deepwater horizon oil rig explosion and blowout	2010	Gulf of Mexico, USA	Estimated between 492,000 and 627,000 tonnes crude oil	• Loss of 11 human lives • Spill over 87 days • 572 miles of shoreline oiled • Thousands of seabirds and marine wildlife including dolphins, turtles, and fish affected
Ixtoc 1 oil well explosion	1979	Bay of Campeche, Mexico	Estimated 454,000–480,000 tonnes crude oil	• Spill over ten months • Spill covered 1100 square miles • Severe damage to marine life
Nowruz oil field spill	1983	Persian Gulf	260,000 tonnes crude oil	• Collision between an oil tanker and the Nowruz Field platform • Spill continued for 7 months
SS *Atlantic Empress*, supertanker, collision	1979	Off the coast of Tobago, Caribbean	287,000 tonnes light crude oil	• Twenty-seven human lives lost • Ship towed out to sea • Much of cargo burnt

(continued)

Table 13.1 (continued)

Name and installation or vessel type	Year	Location	Size of spill	Social, environmental, and economic impacts
Amoco Cadiz supertanker, ran aground	1978	Brittany, France	223,000 tonnes of light crude oil and heavy fuel oil	• Affected 320 km of coastline • Nearly, 20,000 dead seabirds were recovered • Millions of dead invertebrates such as sea urchins and shellfish were washed ashore following the spill • Clean-up operations had a negative impact on the coastal habitats with salt marshes taking many years to recover
M/T Haven tanker, explosion	1991	Genoa, Italy	144,000 tonnes crude oil	• Six human lives lost • Leaked oil for 12 years • Affected Italy and France
SS Torrey Canyon oil tanker grounding	1967	Isles of Scilly, UK	119,000 tonnes crude oil	• Largest vessel to be wrecked at the time • Over 40 years after the spill a bio-remediation project was initiated to speed up the breakdown of the recovered oil
Sanchi oil tanker collision, fire	2018	Off Shanghai, China	136,000 tonnes of ultra-light crude oil (condensate)/2000 tonnes bunker oil	• Thirty-two crew members died • Ship burnt and drifted for a week before sinking

(continued)

Table 13.1 (continued)

Name and installation or vessel type	Year	Location	Size of spill	Social, environmental, and economic impacts
MV Prestige	2002	Off the Atlantic coast of Spain	63,000 tonnes of heavy fuel oil	• Fisheries bans lifted nearly a year later • Four years after, the health of the mussels and environment in Galicia and on the Basque coast had not returned to pre-spill conditions • Total losses for the northern Spanish and Basque coasts fishing industry were estimated at over €296 million
Exxon Valdez struck a reef	1989	Prince Willian Sound, Alaska	37,000 tonnes crude oil	• Affected 2100 km of coastline • More than 1000 sea otters and 35,000 birds known to have died • Twenty-five years later, some species including salmon and sea otters had recovered, but others remained in recovery, with some, including a pod of killer whales, pigeon guillemots, and herring, not recovering

(continued)

Table 13.1 (continued)

Name and installation or vessel type	Year	Location	Size of spill	Social, environmental, and economic impacts
MV Erika	1999	Off the Atlantic coast of France	15,000 tonnes	• Estimates of losses for the tourism industry between 2002 and 2006 set at nearly €719 million • Figures do not include the shoreline cleaning, environmental damage, or public administration costs
MV Selendang Ayu suffered engine failure, drifted for 2–3 days, ran aground	2004	Off the Aleutian Islands, Alaska	1200 tonnes of oil fuel	• Six crew members died during the rescue operation • Around 138 km of Unalaska Island coastline was affected by the spilled oil • Three years later, sea ducks still had elevated body burdens of oil derivatives • After 4 years, oil still recorded at 21 of 24 beaches
MV Treasure structural damage to the ship following bad weather	2000	Off the coast of South Africa	Estimated 400 tonnes of fuel oil	• Temporary closure of South Africa's ports • Threatened species, included penguins and seals • Greatest impact was on declining penguin colonies as the spill happened during the breeding season • Over 20,000 oiled penguins were recovered and treated

(continued)

Table 13.1 (continued)

Name and installation or vessel type	Year	Location	Size of spill	Social, environmental, and economic impacts
MV Solomon Trader grounded on the coral reefs	2019	In the Solomon Islands	Estimated 100 tonnes of heavy fuel oil	• Polluted three miles of reefs and coastline • Local communities had to stop fishing • Children could not play in the water • Local freshwater springs were reported as contaminated • Clean-up costs estimated in the region of tens of millions of dollars

Responding to an Oil Spill

In the ocean, oil can be transported over large distances, dependent on the local currents and wind conditions. Oil type, accessibility of the spill, weather conditions at the time of the spill, presence of local communities, important habitats, and wildlife populations will all influence the response effort. As soon as oil is spilled, it starts "weathering". Some oil will evaporate, and some will disperse and dissolve into the seawater where it becomes available to the marine wildlife swimming in the water column. Oil will also be mixed with water forming an emulsion, and some could sink into seabed sediments where it can persist for months or even years. Oxidation will also take place at the sea's surface, and biodegradation will occur as oil sinks into the water column. The type of oil, weather conditions, and thickness of oil slick will determine which of these weathering processes is dominant. Lighter oils evaporate and disperse more quickly than heavy oils. Strong winds will spread a slick further, affecting a larger area, but will also help with dispersing the lighter oil components. Wave action will help with dispersion but also drive emulsification of heavier oils leading to the creation of emulsified oil which is much harder to break down and disperse and creates much larger volumes of oily mixtures. Even once the oil has disappeared from the sea surface, it continues to pose a threat to marine wildlife and habitats.

Controlled burn of oil on the surface of the Gulf of Mexico near BP's Deepwater Horizon spill source. *Credit* Daniel Beltrá

Responding to an oil spill is important, but it is impossible to recover all the oil spilled, and sometimes only a small percentage, as little as 10%, can be recovered. Booms can be used to contain the oil and to protect economic interests, habitats, and wildlife populations. Skimmers can be used to recover the oil from the sea surface, while chemicals can disperse the oil and speed up natural degradation. Sometimes it is possible to burn the oil while it floats on the sea surface. All methods however have their limitations—skimmers can get clogged by heavy oils, dispersants are toxic to other marine life, and collection of oil and oil mixed with sand, pebbles, and beach debris can be damaging to the shoreline wildlife and habitats. It is also necessary to consider how recovered oil and oiled material will be stored and treated. In many remote locations such as the Arctic, there will be limited options for containing the material recovered and for further treatment or disposal.

Following an oil spill and clean-up operation, long-term monitoring of the spill impact and recovery is very important, particularly in low energy environments such as salt marshes, mud flats, seagrass beds, and mangroves where oil can be trapped and persist for many years. Even with comprehensive recording of the impact of a spill, the full cost in terms of wildlife and habitats will often not be fully evaluated. In most cases, many oiled seabirds will never be recovered, they will die at sea and disappear. The impact on marine mammals caught up in spills, inhaling fumes, or feeding on contaminated fish and invertebrates, may not be evident for months or even years. Often it is not possible to evaluate the impact on plankton, the loss or reduction in numbers of shoreline or benthic invertebrates, or changes in algal cover on miles of coastline. Studies can provide estimates and should out of necessity continue for years—the full recovery of all wildlife populations following the *Exxon Valdez* spill in Alaska had not been achieved 25 years after the spill, and long-term impact following the Deepwater Horizon oil spill on dolphin populations in the Gulf of Mexico will take years to fully evaluate.

Box 1: Findings of the US Federal Government's Programmatic Damage Assessment and Restoration Plan for the Deepwater Horizon Spill

- Nearly, all 21 species of dolphins and whales in the Northern Gulf have injuries, and the population of spinner dolphins could take approximately one hundred years to fully recover.
- As many as 167,000 turtles were killed during the disaster, nearly a quarter of the Sargassum habitat important for juvenile turtles was heavily oiled.
- Between two and five million larval fish were directly killed, while a number of species of adult fish have been documented with oil spill injuries including skin lesions, rotting fins, and oil in the livers.
- Oil and oil spill response efforts killed up to 8.3 billion oysters.
- At least 93 species of bird were exposed to the oil, with estimates that between 10,000 and 19,000 brown pelicans died. The resulting loss of birds would likely impact food webs of the Northern Gulf of Mexico.

- The impact to seabed habitats in the Gulf could take decades to hundreds of years to fully recover.
- Ten years after the accident, the final impacts of the spill were still being evaluated.

International Efforts to Reduce the Risk of Oil Spills and Intentional Discharges

Between the 1960s and 1990s, large accidental oil spills were one of the most visible pressures on the ocean. Major oil tanker spills and sabotage of oil wells and pipelines resulted in news headlines showing wildlife and beaches smothered in oil and devastated communities trying to clean-up. Efforts to improve the safety and management of shipping oil cargoes reduced the number of large oil spills. However, spills and discharges continue to damage marine life and ecosystems, particularly on a local scale. Preventing oil spills is by far the best option.

Oil spills and oily discharges from shipping are regulated by the International Maritime Organization (IMO). Governments that sign up as members of the IMO accept rules for their countries on the safety and security of shipping and preventing marine and atmospheric pollution. Governments then regulate oil spills or discharges at a national level. Where there is the potential for spills to affect the waters and wildlife of more than one country, countries cooperate with one another to set regional regulations. In the North Sea (one of the busiest oil production regions), for example, a regional group regulates discharges of the water produced during the extraction of oil which is contaminated with oils and chemicals. The IMO also designates Particularly Sensitive Sea Areas (PSSAs)—areas of special ecological, socio-economic, or scientific importance which are vulnerable to shipping activities, particularly pollution. In these areas, protection measures are applied which reduce the likelihood of an oil spill. For example, in the Torres Strait, an area of ocean between Australia and Papua New Guinea, a two-way shipping route has been introduced to reduce the risks of collisions and groundings. Other shipping management measures include identification of areas for ships to avoid and deep-water routes.

The most important agreement aimed at preventing oil pollution from shipping is the International Convention for the Prevention of Pollution from ships or MARPOL Convention. It was accepted by IMO members in the 1970s and includes regulations to address accidental oil spills and operational discharges. To minimise the risk of oil spills, the MARPOL Convention requires oil tankers to have structural barriers like double hulls and additional protection for fuel tanks. In addition, ships are required to monitor and control the discharge of oily wastes, to have an oil pollution emergency plan, and ports are required to provide reception facilities so that ships can discharge oily wastes on return to port. The Convention also bans the use and carriage of heavy fuel oils in the Antarctic, and similar protection is being called for to protect the wildlife and Indigenous communities in the Arctic. The Convention identifies Special Areas where the amount of oil that can be legally discharged from ships is severely restricted. Special Areas include the Mediterranean, Baltic, Black and Red Seas, the Middle East Gulfs, Gulf of Aden, and waters of Northwest Europe and Antarctica. Similar restrictions have also been introduced in the Arctic.

Another international agreement, the Convention on Oil Pollution Preparedness, Response and Cooperation (OPRC), sets out a global framework to address oil spills and responsibilities in the event of an oil cargo or bunker (the fuels used aboard vessels) spill. The OPRC sets out priorities following an oil spill: once risks to human lives and safety have been addressed, the priority is limiting further spillage and then recovering oil and cleaning-up the oil. Operators of all ships and offshore oil installations must prepare detailed plans for responding to incidents, so that there is no delay in responding to a spill; have stockpiles of oil spill response equipment; and run training exercises.

Seabirds covered in oil. *Credit* Mikhail Pyzhov/Greenpeace

What Can I Do?

Most of us feel helpless when a large oil spill happens. Groups fully trained in clean-up techniques or wildlife rescue will respond to a spill. Some of these groups are charities or work on a voluntary basis and so rely on public support, for example through donations. Some wildlife rescue centres and environmental groups, such as International Bird Rescue, have oil spill clean-up facilities and will train volunteers. If you can volunteer your time and labour, it will be necessary to explore what opportunities exist where you live, as it differs from country to country and region to region.

Perhaps most important is to recognise that demand for goods and commodities, in a world that uses fossil fuels to deliver them, drives the risk of oil spills. The volume of goods shipped around the world each year is enormous. In 2018, trade by sea reached an all-time high of 11 billion tonnes, representing over 80% of global trade—see Chap. 12 on Shipping and the Ocean. In addition to oil spills, international shipping is a major source of greenhouse gas emissions. Writing to political representatives or to local media can help to inform others of the issues. It can also provide public support for political decisions and commitments, such as moving away from consumerist policies in countries where it is relevant. Purchasing locally produced goods can help to reduce the level of demand for commodities to be shipped around the world, both reducing the risk of oil spills and reducing emissions from shipping. A lot of people would need to make the shift to have an impact, so supporting public campaigning and political leadership can be a big help.

It is also important to remember that many oil spills and oil discharges do not make headline news, and long after the images have disappeared from screens and social media, there will be impacts. The causes and the consequences of an oil spill need to be well understood, so that lessons can be learnt to prevent a repetition of events. In many countries, anyone can help to inform others of issues and push for answers by writing letters or emails to political representatives to make sure that the answers and the follow-up process are made public, and that those responsible for delivering future protections do a good job.

Recommendations for Further Reading

www.ncbi.nlm.nih.gov/books/NBK220703/
www.imo.org/en/OurWork/Environment/PollutionPrevention/OilPollution/Pages/Default.aspx
Oil spills|National Oceanic and Atmospheric Administration (noaa.gov)
www.hfofreearctic.org
www.bird-rescue.org/get-involved/volunteering-internships.aspx
www.cleanerseas.com/10-worst-oil-spills-in-world-history/

Dr. Sian Prior I studied marine biology and chemical oceanography at Bangor, University of Wales, and completed a Ph.D. at Queen Mary and Westfield College, University of London. I started my career in marine policy working for a trade association representing the interests of the UK ports industry. Later, I moved to working on the development and advocacy of marine policy for WWF and more recently for coalitions of environmental groups. I am incredibly lucky to still be able to combine my training in marine sciences with the development of marine policy. I now appreciate how valuable it was to start my working life focused on port and shipping policy—after all most activities at sea take place from ships or boats. For me, linking science with policy and with law has always been fundamental if the use of coastal and marine resources and management of maritime industries is to be compatible with the protection of marine ecosystems, communities, and wildlife.

Chapter 14
Ocean Noise Pollution

Lindy Weilgart

Introduction

The main point to understand about ocean noise pollution is that sound travels very fast and very efficiently underwater, at almost five times the speed as in air. This means that sounds can sometimes be heard over thousands of kilometers of ocean. In contrast, sound on land only extends to about 1–10 km. Because sound functions so well underwater, marine animals have adapted to using hearing as their main sense. Sight does not work very well underwater. Even in very clear water, you can only see out to tens of meters. So, almost all marine animals use sound to sense their surroundings, communicate with others, for mating, for finding their food, for detecting predators and other hazards, and to find their way. These are all functions that are vital for their survival. They use their ears similar to how we use our eyes. This means that if we flood the ocean with noise, it is as if we are shining a bright light into their eyes, blinding them.

Main Sources of Noise

What causes the ocean to be so noisy? Natural sounds, such as from surf, waves breaking, rain, lightning strikes on the water's surface, and underwater earthquakes and volcanoes, can all be loud, but presumably, marine animals are somewhat adapted to these sounds, as they have been around for millennia. Human-caused or anthropogenic noise is another matter, however, as it is very recent, giving animals no chance to evolutionarily adapt to it. The main sources of anthropogenic noise are as follows: shipping, seismic surveys for oil and gas deposits under the ocean floor,

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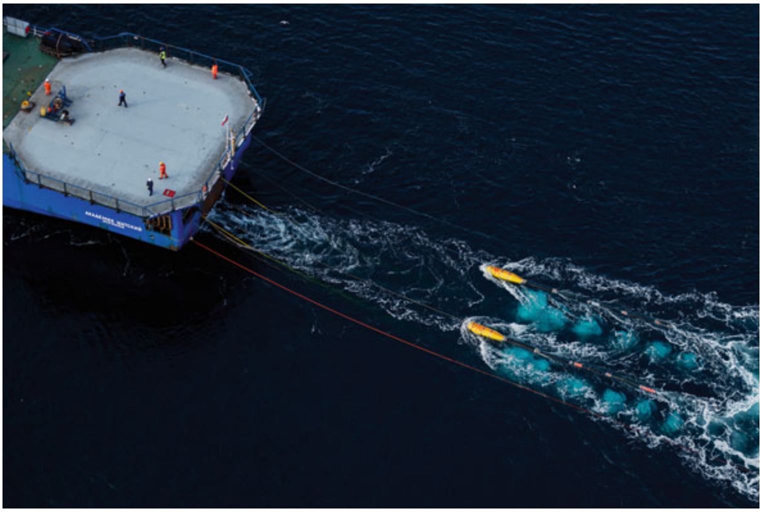
naval anti-submarine warfare sonar, underwater explosions, pile driving to construct bridges or offshore windfarms where large posts or pillars are hammered into the ocean floor, and oceanographic experiments.

Shipping noise is produced mainly from the propeller when ships reach a certain speed. Engines can also transmit noise into the water if they are not well insulated from the hull by, for instance, mounting them on rubber structures. Background noise levels have doubled every decade for the last six decades in certain ocean areas, mainly because of shipping noise. Seismic airgun surveys consist of a ship towing sets of 12–48 or more "airguns" that simultaneously release air under very high pressures so that it sounds like a shot when they go off. The shots are very intense and are almost as loud as a chemical explosion, the loudest human-made underwater sound, aside from an underwater nuclear explosion. The power of an airgun is enough to take your arm off if fired at close range. These shots can penetrate deep, tens of kilometers, into the ocean floor, even after going through thousands of meters of water first. The shots are fired every 10 s or so, around the clock, for months at a time usually. Seismic surveys are going on continuously all around the world, and can be clearly heard 4000 km away, in certain conditions. Naval sonar is used to detect enemy submarines and is particularly loud. Certain kinds of naval sonar can be heard at moderate levels over areas the size of India.



Seismic blasting off Northeast Greenland. *Credit* Christian Åslund/Greenpeace

Impacts of Noise on Marine Animals

It is not easy to detect all the impacts from noise on marine animals in the wild because the ocean is not a controlled laboratory. We cannot hold all the characteristics of an ocean constant and only add the noise, which is what we would need to do to separate out the effects on marine life from the noise alone. Oceans change all the time from one month to the next in hard-to-predict ways. Their currents, chemistry, temperature, amount of plankton, and other factors change for unknown reasons. This makes it hard to link any effects we may observe just to noise and not some natural variation. Moreover, there are other human-caused stressors like chemical pollution and toxins, climate change, and overfishing that are occurring at the same time, so those factors need to be separated out from impacts occurring just from noise as well. We can do studies in the laboratory, but these may not mimic the natural ocean well enough to be useful.

Despite all these challenges, many impacts have been documented from noise on at least 130 marine species, from marine mammals and fish to invertebrates such as plankton, squid, and shellfish. These impacts include higher death rates, greater stress which can damage the immune system and reduce the ability to reproduce, hearing damage, damage to reflexes needed to escape predators, reduced feeding, avoidance of a noisy area which may be important for feeding and mating, "masking" or the drowning out of sounds important to the animals, changes in call rates which can affect mating or contact with group members or young, developmental delays, lower growth rates, organ or nerve damage, disorientation, worse body condition, uncoordinated schooling, decreased fisheries catch rates, and even impacts on ecological services performed by invertebrates such as water filtration and releasing nutrients from the seabed to the ocean. Ocean noise pollution can affect the entire marine ecosystem and how species interact with one another. It degrades the quality of the marine environment, preventing or hindering animals from hearing their prey or predators, hearing others in their group, or orienting and sensing their environment.

Whales

Finback whales stopped singing for periods of months during seismic airgun surveys, only resuming singing once the surveys and noise ended. Finback males sing to attract mates, similar to birds, so when they stop singing, they cannot find mates and cannot reproduce. If animals are not mating during one mating season, it would have severe implications on the health and welfare of the population. Finback whales also avoided seismic surveys, meaning they moved away from their preferred areas. Bowhead whales in the Arctic fell silent when seismic survey noise reached a certain high level. At the lowest levels, as soon as the noise became just detectable, the whales increased their rate of calling compared to without seismic survey noise, in an apparent attempt to overcome the noise. As the noise progressively increased, the calling rate also increased until the noise got too loud. Then the whales seemed to give up, reduce their calling rate, and eventually falling completely silent once the noise got even louder. Narwhals appear to have been prevented from returning to their more southerly wintering grounds because seismic airgun surveys were blocking their migration route. Instead, they stayed in their summering grounds, becoming fatally entrapped in ice. In another study, stress hormones were measured in the feces (poop) of North Atlantic right whales. During the 9/11 attacks, when there were dramatically fewer ships in the area and the measured shipping noise levels were lower, the whales' stress hormones were also much lower (though ours were much higher!). In the subsequent four years, when shipping noise was more typical and higher, the hormones were also much higher. During the height of the COVID pandemic lockdown period, shipping noise also dramatically decreased, with noise power being reduced by almost half compared to the same period in 2019. Shipping noise as well as seismic airgun noise can also affect whale feeding, interfering with how efficiently they can find prey.

Naval anti-submarine warfare sonar, used to detect enemy submarines, has shown itself to be dangerous to whales, perhaps particularly to a set of species known as the beaked whales. These are very deep divers, regularly descending to depths of thousands of meters. The sonar appears to cause a panic reaction in them, whereby they change their dive pattern which, in turn, produces decompression sickness, i.e., the diver's "bends", in them. Whales can hemorrhage from their brain and heart and other vital organs, sometimes dying within 4–24 h. They can fatally strand on beaches or die at sea. When many individual whales, especially of different species, strand over many kilometers of beach, all at about the same time, we scientists suspect the cause has to do with noise, since no other pollutant besides sound travels so quickly so far. A 15-year field study off the Bahamas showed that the beaked whales living on naval ranges, on which sonar exercises are common, produce fewer calves than those living 170 km further away. It is an especially serious effect when reproduction is impacted, as then the health of the population is jeopardized. Of course, we can wonder why beaked whales live in these often noisy places at all. It is possible that there are some features to this naval range which make it an otherwise good habitat for beaked whales, such as an abundance of prey, so that they put up with the sonar, though cannot reproduce as well there. The whales seem to move off the range during sonar exercises, but this leaves them with fewer energy reserves as they must travel, which costs them energy as well as missed feeding opportunities.

Fish and Invertebrates

Developmental delays and body malformations were discovered in scallop larvae in tanks exposed to seismic airgun shots. Even microscopic zooplankton suffered higher mortality rates from noise from a single seismic airgun. Zooplankton, along with phytoplankton, form the foundation upon which the whole ocean ecosystem depends. Zooplankton are an essential food source for whales but also fish, larger invertebrates (oysters, clams, crabs, shrimp), and seabirds. A large kill zone or "hole" in zooplankton numbers formed in the wake of the airgun, with impacts extending out to at least 1.2 km. Zooplankton numbers dropped to half in most of the species. There were 2–3 times more dead zooplankton overall, with all krill larvae killed. Low-frequency (or pitch) sound caused massive, fatal injuries in squid and octopus. In two separate years, a total of nine giant squid fatally mass stranded together with seismic airgun surveys, showing extensive damage to their organs. Hearing impairment has been shown in various fish species exposed to even moderate noise. Some fish recovered after 2 weeks, but because these fish are very dependent on their hearing for most life functions, would have been very vulnerable to predation during this time and left with limited ability to detect their prey. Other fish showed no recovery to extensively damaged ears from a seismic airgun, even after 58 days. Stress responses, which can impact the immune response and reproduction, have been shown in several fish and invertebrate species when subjected to noise. Death rates were five times higher in scallops due to seismic airgun shots in the field. Altered reflex responses, which are necessary to escape predators, persisted at least 4 months after the airgun noise had stopped. In lobsters, these impairments lasted even at least a year after the end of the airgun shots. Airgun noise also weakened the immune response in lobsters up to at least 4 months after the end of the airgun emissions.

Boat noise interfered with how parents cared for their young and nests in various fish species, causing fewer young to survive. Reproduction in one species was impaired by noise because there was less courtship involving sounds (mating songs). Another species showed fewer eggs in each nest in noisy sites compared with quieter ones. Feeding attempts were suppressed in the presence of noise. All these reactions can affect the health of the population. Most worrisome is when noise affects ecosystem services such as the filtering of water or mixing of mud or sand layers on the sea floor which makes nutrients available to marine animals.

Cumulative and Synergistic Impacts

Stressors can interact such that the impacts accumulate or add to each other (cumulative impacts) or are even greater than the sum of each individual impact (synergistic impacts). In this way, all the other threats that marine life face in the form of climate breakdown, chemical pollution, ocean acidification, getting caught in fishing gear, getting struck by ships, etc., can interact with noise pollution. For instance, if whales are hearing impaired by noise, they are unable to detect ships in time to avoid them and can get fatally struck. If harbor porpoises are distracted by noise, they are more likely to blunder into fishing nets.

Solutions

Noise is a transboundary pollutant and therefore needs to be managed internationally. Several international fora such as the United Nations, other organizations, and conventions under the UN, such as the International Maritime Organization, the Food and Agriculture Organization, and the Convention of Biodiversity, are already starting to address underwater noise pollution. The most effective mitigation and management approaches for noise are separating the noise in both time and space from marine life and quieting the noise through technological alternatives. The Canary Islands implemented a moratorium on naval exercises in 2004 after which fatal whale strandings stopped. Marine Protected Areas should be managed with noise in mind, including noise buffer zones. Acoustic refuges can preserve still quiet habitat for noise-sensitive species. Shipping noise can be reduced through better propeller and hull design and operational measures such as slowing down ships. Both of these, but especially speed reductions, have the potential to cut greenhouse gases and increase efficiency as well. Quieting the loudest 16% of all vessels can reduce the area degraded by noise by 60%. Port incentives to reward quieter ships through reduced port fees have been successfully implemented in British Colombia, Canada. Quieter technologies such as marine vibroseis are a better alternative to seismic airguns. Marine vibroseis cuts out the unnecessary, wasted energy emitted at the higher frequencies by airguns and thereby prevents whales and dolphins that hear at these frequencies from being as impacted. It also uses a sound that is less damaging to marine life. Of course, an even better solution environmentally would be to leave oil and gas in the ground. Several quieting technologies are available for pile driving that have shown to be effective. Nevertheless, noise requires a precautionary approach due to the large potential area of impact and the difficulty in detecting population and ecosystem impacts.

Ship traffic on the ocean. *Credit* David McNew/Greenpeace

Recommendations of Further Action

The actions to reduce ocean noise pollution often overlap with those to generally lower our footprint on the earth. These include buying less in general, since over eighty percent of the world's goods are transported by sea, wasting less, buying locally produced goods and food, reducing our use of oil and gas by walking, biking, and using public transportation, flying less, heating and cooling our homes less, insulating them better, and increasing fuel efficiency overall. Divesting of oil and gas stocks and maintaining an environmentally and socially responsible investment portfolio are also helpful. Reducing the size of our navies and making sure they are environmentally compliant by writing to our elected officials can also help protect our oceans from noise. Finally, investing in noise reduction technology as well as research and development will help us tackle ocean noise pollution.

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Dr. Lindy Weilgart I have always loved large animals like whales and elephants, because although they have such potential for destruction, they seemed, proportional to their size, mostly quite gentle. I started studying pilot whales in 1982, followed by sperm whales. For both species, I tried to relate the behavior we observed at the surface to the sounds they were emitting underwater at the same time. We even followed sperm whales across the Pacific for one full year in a 13-m sailboat, with my then 5-year-old son and 10-month-old daughter, in an attempt to look for any dialects in the communication sounds of sperm whales. Following this study, I got sidetracked into the issue of underwater noise pollution, because my postdoctoral supervisor was working on a project, called Acoustic Thermometry of Ocean Climate (ATOC) involving broadcasting loud sounds underwater, ostensibly to study climate change. Though it was not my project, I became concerned about the loud sounds affecting the whales. I raised my concerns with my supervisor first, and when that proved unsatisfactory, informed him I would be alerting the media. After a month of my trying, the story finally broke in the Los Angeles Times, on their cover, no less. This unleashed a dam of further news coverage prompting outrage that such a potentially invasive project could go ahead in the U.S. Monterey Bay National Marine Sanctuary. The regulatory agency, the National Marine Fisheries Service, received thousands of faxes in protest over just three days, forcing them to reverse their permit. After serving as whistleblower in this case, I somehow was tied to the issue of ocean noise pollution forever thereafter. So, since 1994, this has been my area of expertise. My M.Sc. (Memorial Univ. of Newfoundland), Ph.D. (Dalhousie), and postdoctoral studies (Cornell) all involved researching whale communication sounds in the wild. More recently, I have worked in the area of ocean policy at fora such as the United Nations, as well as organizations under the UN such as the International Maritime Organization, Convention on Biodiversity, and Food and Agriculture Organization. I am an ocean policy consultant with OceanCare, a Swiss environmental organization, and am an adjunct research associate with Dalhousie University's Biology Department in Canada (*Credit* Ian Willms).

Part IV
Threatened and at Risk Ocean Habitats

Chapter 15
The Deep Sea

Helen Scales

Introduction

The deep ocean makes up the single, biggest portion of the earth's biosphere. Of all the habitable space available for living things to occupy, at least 95% is the deep. Beginning at the 200-m mark, with an average depth of around 4 km and a total volume of roughly a billion cubic kilometres, the deep ocean is inconceivably huge. Contrary to scientific theories of the past, it is not a lifeless, empty void. Despite the darkness, cold and extreme pressure, plenty survives and thrives in the deep. Previously unknown species are continually being discovered there and occasionally whole new habitats. So quite simply, if we want to understand life on earth, then we must look into the deep. The more we learn about the deep, the more it becomes clear that this enormous realm is critical for the health of our whole living planet. We are also learning that its remoteness and size are not enough to protect the deep ocean from human impacts.

A Brief Tour of the Deep

If you were to jump into the ocean and fall into the deep, you would pass through a series of zones. And on reaching the seabed, there is a range of geological features and habitats to encounter.

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F. Obaidullah (ed.), *The Ocean and Us*,
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Twilight Zone: 200–1000 m

Dim blue sunlight trickles down into the twilight zone, although not enough for algae to photosynthesise. Deep food webs mostly rely on organic matter falling from above, largely in the form of dead plankton and their faeces clumped into particles known as marine snow. Lanternfish, krill, vampire squid and many other animals catch marine snow as it falls.

Midnight Zone: 1000–4000 m

There is no sunlight here at all, but it is not completely dark. Many animals in the deep are bioluminescent, including anglerfish, ninja lanternsharks and gossamer worms. They make their own light, to dazzle predators, attract mates and to see through the dark.

Abyss: Below 4000 m

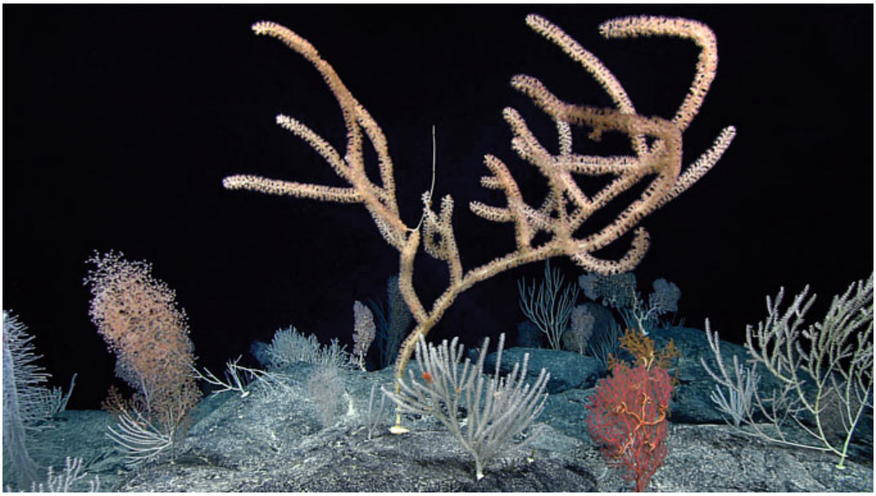
Depending on the location, this can either be seabed or open water.

Hadal Zone, Below 6000 m

It is chiefly made up of 27 oceanic trenches including the deepest, the Mariana Trench, which plunges to just less than 11 km. Amazingly, there are organisms that withstand the colossal pressure in trenches, such as the hadal snailfish—the deepest-dwelling vertebrates.

Abyssal Plains

Swathes of sediments cover more than half of the earth's surface. In some places, the sediments are so thick you would dig through 10 km before reaching the hard rock of the seabed beneath. Abyssal plains are the realm of roaming herds of sea cucumbers that feed on fallen drifts of marine snow. Tripod fish perch on long pectoral fins and sit still, saving energy while they wait for prey to come by.



Diverse, dense coral community on the Debussy Seamount. *Credit* NOAA Office of Ocean Exploration and Research, Deep-Sea Symphony: exploring the Musicians Seamounts

Seamounts

Worldwide, the abyss is dotted with tens of thousands of huge volcanoes (extinct or active) called seamounts. They can be thousands of metres tall without reaching the sea surface. Many are colonised by corals and sponges that create rich habitat for other species. Steep canyons provide similar deep-sea habitat at the edges of continental shelves. Whales, sharks and other migrating animals call in at seamounts, perhaps to feed, mate or find their way.

Hydrothermal Vents

These are the ocean's equivalent of hot springs on land, only far hotter and more toxic. They form mostly at the edges of tectonic plates, especially along submerged mountain ranges called mid-ocean ridges. Seawater percolates through cracks in the seabed and is heated by magma chambers. Scorching fluids pour out of craggy chimneys, known as black smokers (there are also white smokers). The high pressure stops the fluids from boiling, and they can reach hundreds of degrees.

Undeterred by these hostile conditions, giant tube worms, yeti crabs, scaly foot snails and hundreds of other species cluster around vents. They rely on colonies of bacteria that harness energy from chemicals in the vent fluids (mainly hydrogen sulphide and methane) in a process known as chemosynthesis. Many vent animals have Chemosynthetic symbiotic bacteria inside their bodies which provide them food and allow these profuse ecosystems to exist entirely to cut off from sunlight.

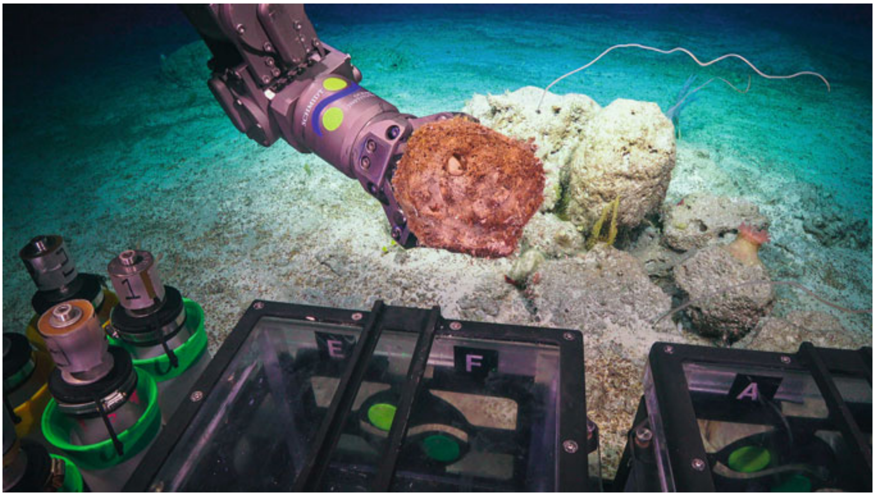
How to Study the Deep

Deep-sea science is not easy or cheap. Deep waters are mostly in remote regions, far from shore and accessible only from large ships on long journeys—referred to as cruises.

People can make relatively brief visits into the deep inside a handful of human-occupied research submersibles, such as Alvin run by the Woods Hole Oceanographic Institution in Massachusetts. Much new knowledge about the deep is coming from teams who stay on the surface or on land. Deep-diving robots (known as remotely operated vehicles, ROVs) are controlled along an umbilical tether from a ship. Equipped with cameras and robotic arms, they give scientists eyes and hands in the deep. Other machines roam untethered through deep. Known as autonomous underwater vehicles, AUVs, they can operate for weeks and months, before returning to the surface for retrieval.

Other technologies are deployed to study deep-sea physics, chemistry and biology. Permanent arrays of sensors, fixed in place or allowed to drift around, monitor the temperature and composition of open waters. Others listen for subsea tremors in deep-sea trenches to forecast earthquakes.

Given the costs, deep-sea science has not traditionally been accessible to scientists from low-income nations. Efforts to make it more inclusive include bringing together more diverse teams on research cruises and developing more cost-effective technologies. One such device is a miniaturised free-fall lander developed by the National Geographic Society. This small camera with bait attached works down to 6000 m, filming continuously as animals come to feed, until the pre-programmed release lets it float back up.



ROV SuBastian with careful guidance by its pilots uses the manipulator arm to collect a geological sample at 500 m on Flinders Reef. *Credit* Schmidt Ocean Institute

Why the Deep Ocean Matters

Due to its colossal size, the deep ocean plays a vital role in the earth's climate. If the ocean in all its deepness wasn't there, air temperatures would be 30 °C higher than today. More than 90% of the extra heat trapped in the atmosphere by greenhouse gases has been absorbed into the ocean, much of it into the deep. What's more, currents circulating through the deep distribute the sun's heat that beats down at the equator, making much of the earth habitable.

The deep also holds a huge carbon store. Organic matter sinks as marine snow and is also actively drawn down by hordes of animals that swim up and down the water column every night and day, in the biggest animal migration on earth. When it reaches the deep, much of that carbon stays away from the atmosphere for hundreds, even thousands of years. In total, around a third of all of humanity's carbon emissions have been absorbed into the ocean.

Scientists are also looking into the deep for biomedical inspiration. Corals and sponges are especially promising in the search for molecules that could lead to new generations of pharmaceuticals, including much-needed antibiotics. Already hundreds of chemicals have been found in the deep that kill cancer cells and pathogens. Compared to terrestrial and shallow water equivalents, natural chemicals from the deep are often far more complex and toxic—precisely the qualities scientists are seeking. Exploring these largely untapped chemicals causes minimal ecological impact. Biodiscovery programmes use remote technologies to take small, selective samples of animals and microbes to bring back and study in the laboratory.

There are other more esoteric although no less important reasons that the deep ocean matters. This could be where life on earth first began. A leading theory places the origins of living cells billions of years ago within the chimneys of hydrothermal vents. Structures found in ancient rocks, between 3.77 and 4.28 billion years old, could be the fossilised remains of very early microbes that formed at hydrothermal vents. It would have required a certain type of vent, with the necessary chemical composition and not so hot as to boil the first glimmers of life as soon as it formed. The Lost City in the Atlantic Ocean is the only known example of this kind of hydrothermal vent in the ocean today.

Threats to the Deep

Humanity's collective impact on the earth is pushing ever deeper into the ocean. People are turning to the deep to exploit resources that used to be out of reach, partly because they now have the technologies to do so. There is also a growing sense that the earth's resources are being pushed too far, and supplies of the substances and food humans demand are running out. Maybe the deep ocean is the solution to our troubles.

The problem is that deep ocean ecosystems operate in fundamentally different ways to those on land and in shallower seas. Many deep-sea organisms are extraordinarily long-lived and sensitive to disturbance, reducing their capacity to recover from habitat loss and exploitation. How humans operate in the deep is also very different. It is far more challenging to monitor activities and enforce regulations here than just about anywhere else. And we still have a great deal to learn about the deep ocean and how it works. Scientists face a tremendous task of predicting what the combined impacts could be of fishing, mining and pollution.

Deep-Sea Fishing

With bigger, more powerful ships and equipment, many industrial fishing fleets are moving offshore and focusing their fishing power in deeper waters. A classic case of the environmental destruction caused by deep-sea fishing is that of the fish orange roughy. Trawlers originally targeted orange roughy as they spawned on seamounts off New Zealand and Australia. Enormous catches were hauled up, along with smashed remains of corals snagged from the seamounts. The catches quickly collapsed, and the fisheries moved from one seamount to the next, sweeping through the ocean like mining operations.

It has been several decades since orange roughy fishing boomed, but still the fish and the seamount ecosystems are showing only meagre signs of recovery. Orange roughy and deep-sea corals can live for centuries and take a long time to mature and reproduce. Other deep-sea species share a similar long, slow life history, including deep-sea sharks which are exploited for their livers that are rich in squalene, an ingredient used in cosmetics and haemorrhoid creams.

Plans are underway for a new type of deep-sea fishing. Huge shoals of lanternfish live in the twilight zone. Estimates suggest there are between 10 and 20 gigatonnes worldwide, compared to the total wild fisheries catch of around 0.1 gigatonnes annually. Lanternfish are too bony for human consumption but could be rendered into fish meal and oils to feed farmed salmon. Twilight zone fisheries would not impact the seabed because the trawl nets would operate in midwater (although bycatch of other species could be an issue) and unlike orange roughy, lanternfish are short lived and fast growing, suiting them better to sustainable fishing. However, they play a poorly understood but likely critical role in drawing down carbon during their daily migrations to the surface and back. Exploiting lanternfish could disrupt the deep ocean's ability to sequester carbon.

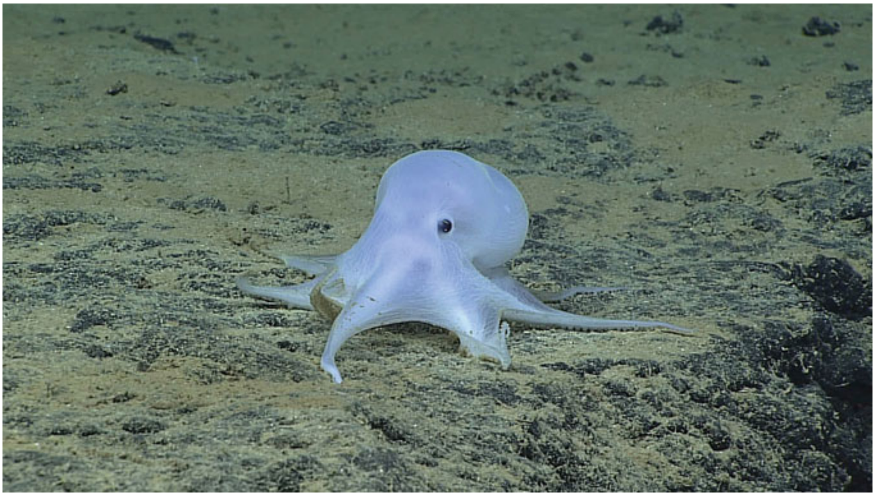
Deep-Sea Mining

The 2020s is the decade in which various nations and corporations hope to begin mining minerals from the deep seabed. The situation has changed a great deal since people first considered deep-sea mining several decades ago. Technologies are now available to make this ambition a reality. There is also an added complication: the deep seabed is officially the common heritage of humanity—it belongs to all of us, people alive now and in the future. As part of that designation, the International Seabed Authority (ISA) was set up to oversee seabed activities on behalf of humanity. It is the ISA's responsibility to develop seabed mining, to ensure the proceeds are shared out fairly, and crucially that mining causes no environmental harm. So far, these are proving difficult tasks to achieve.

Arguments in favour of seabed mining include the decline in easily mineable ores on land. There is also growing demand for particular metals for green technologies, including electric vehicle batteries, wind turbines and solar panels. Those who wish to mine the deep claim that seabed minerals will be the key to solving the climate crisis.

Meanwhile, there is growing pressure for a global moratorium on deep-sea mining, coming from scientists, civil society groups, governments and corporations who are all concerned about the industry's environmental impacts. Likely impacts of mining the three main targets (see Deep-Sea Mining) include destruction of species and habitats, noise pollution, disruption of carbon stores and production of sediment plumes that could contaminate ecosystems far from the mining sites. Many questions remain unanswered, including how acute and long-lasting the impacts would be and whether this is the best option for using the earth's precious resources. Alternatives to seabed minerals could be used in green technology, and supplies of land-based ores would last longer within a closed-loop economy.

Time will tell whether the ISA will give the go-ahead for seabed mining and ultimately whether this dream will become a utopia or dystopia.



Dumbo Octopus. These animals live in the deep ocean. Deep-sea octopuses have recently been found to lay eggs around the polymetallic nodules, and deep-sea miners are seeking to exploit. *Credit* Schmidt Ocean Institute

Deep-Sea Mining

Three main kinds of deep-sea mining are in the planning stages:

Abyssal Plains

Target: polymetallic nodules

Depth: 4000–6000 m

Metals: cobalt, nickel and copper

Hydrothermal Vents

Target: sulphide minerals inside black smoker chimneys

Depth: 1000–4000 m

Metals: copper, zinc, gold and silver

Seamounts

Target: metal-rich crusts

Depth: 800–2500 m

Metals: cobalt and tellurium

How Deep-Sea Mining Would Work?

1. Mining machinery would be remotely operated from a ship at the surface. On seamounts and vents, machines would drill ores from the seabed. On abyssal plains, they would scoop up rocks lying loose on the sediment.
2. Extracted ore would be pumped up a pipe to a ship.
3. The ore would be de-watered and contaminated tailings pumped back into the sea, perhaps into the twilight zone around 1000 m down.

Plans for mining abyssal nodules in the Clarion Clipperton Zone in the central Pacific foresee continuous operation for several decades. Dozens of mines would each exploit hundreds of square kilometres of seabed per year.

The ISA sells prospecting licences for blocks of seabed commonly around 80,000 square miles in size. One such permit has been given to the hydrothermal vent system at the Lost City.

Pollution

The deep ocean has long been a repository for human wastes. During the twentieth century, it is thought at least a million tonnes of unwanted and rotting chemical weapons and munitions were dumped in the deep. The exact location of those dump-sites remains worryingly unknown, although some have been found such as one off the coast of California in 2021. What to do with these dangerous pollutants is another unanswered question.

It is now illegal to dump anything in the ocean except for a few permitted substances, including animal waste. However, it comes as no surprise that persistent chemical pollutants, such as PCBs, as well as ubiquitous plastics are finding their way into the deep. Microplastics contaminate marine snow and accumulate on the seabed in some places in startlingly high concentrations. Scientists have yet to determine the full impact plastics have on deep-sea species, populations and ecosystems.

In Summary

The deep ocean is by no means immune to the threats of the Anthropocene, but in many ways is in better shape than other parts of the living planet that have suffered far longer from human presence and influence. There are still relatively untouched populations of wild animals in the deep and places that do not bare obvious signs of destruction and diminishment from overexploitation and pollution. And there is a possibility of keeping it that way.

The deep offers the opportunity to avoid making the same old mistakes that humanity has made repeatedly on land and in shallower seas. We still have the option of embracing a precautionary approach to humanity's dealings with the deep. It would be feasible to halt some of the most destructive industries before they begin, instead of trying to figure out how to clean them up and restore balance afterwards.

The burden of proof can be firmly shifted away from those who wish to protect the deep ocean, onto those who wish to exploit it. Extractive industries should be required to demonstrate beyond any reasonable doubt that their activities will not cause unacceptable harm to the very systems on which so much of life on earth depends. Removing the threat of damaging exploitation in the deep would leave scientists to continue their work of exploring and understanding this fascinating and important part of our planet, because there will always be more to know.

Further Action

Very few people will ever visit the deep sea, or even get close, but anyone can get involved in helping to safeguard it. Follow and support the work of various groups campaigning for deep-sea protection. Put pressure on your elected officials to reject damaging deep-sea industries. Pay close attention to the source of seafood you eat and avoid species from the deep. Be interested and learn more about the deep, talk to your friends and family about it and help make this hidden place as cherished as any other part of this amazing living planet of ours.

Further Reading and Exploration

Scientific Papers

Callum M. Roberts, Julie P. Hawkins, Katie Hindle, Rod.W.Wilson, and Bethan C. O'Leary, Entering the Twilight Zone: The Ecological Role and Importance of Mesopelagic Fishes. (np: Blue Marine Foundation, 2020), https://www.bluemarinefoundation.com/wp-content/

Fauna & Flora International, An Assessment of the Risks and Impacts of Seabed Mining on Marine Ecosystems (Cambridge: Flora and Fauna International, 2020), https://cms.fauna-flora.org/wp-content/uploads/2020/03/FFI_2020_The-risks-impacts-deep-seabed-mining_Report.pdf

Thomas J. Webb, Edward Vanden Berghe, and Ron O'Dor. Biodiversity's Big Wet Secret: The Global Distribution of Marine Biological Records Reveals Chronic Under-Exploration of the Deep Pelagic Ocean. PLoS ONE. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0010223

Websites

Deep-Sea Biology Society https://dsbsoc.org/

Several Organisations Broadcast Live Feeds of Their Deep-Sea Expeditions

NOAA, Okeanos Explorer https://oceanexplorer.noaa.gov/livestreams/welcome.html
Ocean Exploration Trust, Nautilus https://nautiluslive.org/
Schmidt Ocean Institute, Falkor https://schmidtocean.org/technology/live-from-rv-falkor/

Organisations Campaigning to Protect the Deep

Deep-Ocean Stewardship Initiative https://www.dosi-project.org/
Deep-Sea Conservation Coalition http://www.savethehighseas.org/
Short film explaining what deep-sea mining is and the threats it poses: In Too Deep: The True Cost of Deep-Sea Mining https://youtu.be/bUCk_THAPNQ

Dr. Helen Scales My fascination and love of the ocean began between the tides on childhood holidays to the UK's southwest, Atlantic coast, and since then has been gradually sinking deeper. I first learnt to scuba dive in those waters before heading off to more distant seas. My ocean studies have taken me from the mangroves of Madagascar and remote coral reefs off Borneo, to West African oyster forests and the deep waters of the Gulf of Mexico. While exploring the seas, I discovered a love of words and rather unexpectedly became a writer. I have written several books about the ocean for adults and children, including my recent exploration of the deep, *The Brilliant Abyss*. I also teach at Cambridge University, and I advise the marine conservation charity Sea Changers. And when I am not further afield, you might find me back in the Atlantic, on the wild west coast of France.

Chapter 16
Coral Reefs

Reem AlMealla

Introduction

Coral reefs, sometimes known as the rainforests of the ocean, cover less than 0.1% of the ocean floor, yet host the highest concentration of marine biodiversity in the world's oceans. This amounts to one quarter of all recognised marine species making them extremely important ecosystems that support biodiversity.

What Are Coral Reefs?

Coral reefs are geomorphic structures built from a calcium carbonate ($CaCO_3$) skeleton. They are ancient ecosystems that date back ~500 million years. For reference, dinosaurs are estimated to date back 65 million years. Coral reefs were built over time through the production of layers of calcium carbonate creating an important three-dimensional structure. This structure provides food, habitat and interaction space for numerous associated species.

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Aerial view of the Great Barrier. *Credit* Michael Amendolia/Greenpeace

What Are Corals?

Corals are animals, not plants as many people believe. They belong to a fascinating group called Cnidaria all of whom come in various forms, shapes, sizes and colours. All members of this group are invertebrates which means they have no backbone. They are very simple creatures and have no organs such as heart or lungs. However, they do all share one distinguishing characteristic: a simple stomach with a single mouth opening surrounded by stinging tentacles. Members of the Cnidaria group include jellyfish, sea anemones and sea pens. In addition to having a radial symmetrical body, the two major body forms are as follows: (1) they either have a polyp as is the case for corals or (2) they have a medusa as is the case for jellyfish.

When it comes to corals, each individual coral animal is considered a polyp; a large group of polyps (with identical genetics) together form a coral colony. Corals can exist as a solitary single polyp, e.g. mushroom corals (*Fungia* sp); however, most corals are colonial organisms, living with hundreds of coral polyps all connected to each other, e.g. brain coral (*Diploastrea* sp).

How Do Corals Build Their Skeleton?

Just like trees and plants use sunlight to grow towards the sky, coral polyps use the aragonite ions (a form of calcium carbonate) present in the ocean water to produce their exoskeleton outside their body. They construct a framework of aragonite crystals to grow in a vertical manner towards the sunlight and will also grow in a horizontal manner where possible. The coral polyp body is usually shaped in the form of a cylinder with its mouth at one end, surrounded by arm-like tentacles that gather food and sting other organisms that threaten them. Coral polyps have no anus, and following food digestion, the waste products are released through the mouth.

How Do Corals Reproduce?

Corals reproduce either asexually or sexually. Asexual reproduction in corals happens either by budding (a small new baby polyp grows itself from the original polyp) or fragmentation which is when a piece of the coral colony is broken and then grows apart from the mother colony. Sexual reproduction also happens in some coral species (e.g. brain coral) through a process called spawning whereby an egg and sperm are released into the water column. There are over 6000 known species of coral, classified either as hard corals (also known as hermatypic corals) or soft corals (ahermatypic corals). Hard corals are those that form reefs, i.e. produce/secrete a calcium carbonate skeleton whilst soft corals do not have a calcareous skeleton and hence do not form reefs. Similar to hard corals, soft corals also live as colonies of polyps and often resemble brightly coloured plants (but are animals!), e.g. sea fans, sea feathers and sea whips. Corals can live for several thousands of years with some deep-sea coral species recorded to live >4200 years, e.g. *Leiopathes* sp. (a soft coral) whilst others such as *Gerardia* sp. lives for >2500 years. In addition, shallow water corals can grow between 10–20 cm per year depending on the species, whilst deep-sea corals grow at a slower rate with approximately 10 mm per year. Therefore, current corals worldwide have been actively growing for the last thousands of years.

The Coral Holobiont

Corals harbour a symbiotic relationship with a single-celled dinoflagellate microalgae (commonly known as zooxanthellae) from the family Symbiodiniaceae, which is believed to be the foundation of coral reefs. The zooxanthellae symbiont (which is technically a plant) lives within the tissue of the coral polyps and supplies the coral with 95% of its nutrition through the process of photosynthesis. This energy supply by the zooxanthellae is used by the coral to build the reef through the process of calcification. In addition, the zooxanthellae provides corals with their distinctive bright colours. In return, the zooxanthellae receives shelter and crucial plant nutrients such as ammonia and phosphate from the coral's waste, which it uses for photosynthesis.

Just as humans have their gut microbiome that lives in the digestive tracts and is essential for human development, immunity and nutrition, corals too host large populations of microorganisms such as eukaryotic algae, bacteria, viruses, fungi and archaea in their mucus layer, skeleton and tissues whereby the zooxanthellae is just one. This diverse and dynamic group of microbial communities is collectively referred to as the coral holobiont. The coral holobiont provides their host with benefits as a result of various mechanisms, including photosynthesis, nitrogen fixation, the provision of nutrients and infection prevention, thereby contributing towards coral health. In addition, the external environmental conditions determine and influence the members of the coral holobiont thereby making it a dynamic system. Hence, any change in the environmental conditions will impact the coral holobiont and cause change to the relative abundance of microbial species in order to adapt to the new condition.

Where Are Corals Found?

Corals are found throughout the world's oceans including tropical, sub-tropical, temperate and polar areas. They are able to live in shallow and deep water. The majority of reef building corals are mainly found in tropical and sub-tropical areas located between the Tropic of Cancer and the Tropic of Capricorn. These coral reefs thrive in clear and shallow waters (<25 m) where temperatures range between 18–32 °C and salinity is between 32–35 parts per thousand (ppt). Some coral reefs are able to withstand extreme environmental conditions such as those that exist in the Persian-Arabian Gulf, which hosts the hottest sea on the planet. Temperatures in this region are between 16–36 °C, whilst salinity ranges between 40–70 ppt. Coral reef formation is influenced and limited by factors such as temperature, depth, salinity, turbidity (which is related to sedimentation) and air exposure.

Contrary to shallow water corals, deep-sea corals (also known as cold water corals) exist in waters up to 6000 m below the ocean's surface and are distributed worldwide. They live in cold conditions (as cold as -1 °C) with little to no light and have been observed off the coast of Antarctica. Deep-sea corals have also been recorded in the waters of Japan, Norway, UK, Australia and New Zealand amongst others. What makes these corals fascinating is that despite the icy and dim conditions, they have been observed to thrive in abundance creating lush deep-sea coral gardens. They appear to be very similar to shallow corals in terms of biology and diversity with over 3300 species identified so far. Deep-sea corals exist either in solitary form or in colonies and rely on their ability to capture tiny organisms that drift with the currents to obtain the necessary nutrients and energy required to survive their harsh environmental conditions. Similar to shallow corals, some species of deep-sea corals are also considered reef building, e.g. *Madrepora* sp. and *Lophelia* sp. Deep-sea corals remain understudied although advancements in technology enabling access are enhancing research and exploration.

Importance of Coral Reefs

Coral reefs are of great importance to the world both in terms of ecology and economy as they benefit approximately one billion people through their ecosystem services. Some of these services include coastal protection where coral reefs contribute towards dissipating 97% of wave action energy—storms and floods that would otherwise hit shorelines, impacting some 200 million people who live below 10 m elevation and within 50 km of reefs. Reefs contribute towards reducing annual expected damages from storms across reef coastlines by more than $4 billion. Furthermore, they are estimated to generate income through reef tourism worth some US $35.8 billion dollars per annum globally. Ecologically, coral reefs support the largest number of marine species per unit area than any other marine ecosystem. Coral reefs support approximately one billion people that rely on these reefs for food, for many their primary source of protein, and income. In addition, coral reef fisheries are globally estimated to be worth $6.8 billion a year. Despite their high ecological, economic and recreational value, coral reefs worldwide are highly threatened and are witnessing a sharp and serious decline.

Solitary coral polyp. *Credit* Hani Bader

Threats to Coral Reefs

Globally, coral reef ecosystems are in decline with an estimated 30% of reefs already lost or severely damaged. Predictions are that 60% of reefs will be lost by 2030. This loss is driven by global phenomena related to climate change such as ocean acidification and rising ocean temperatures combined with local stressors such as overfishing, declining water quality associated with nutrient runoffs and excessive sedimentation. These combined stressors influence coral mortality and reproduction rates resulting in reduced coral growth which contributes to the overall degradation of reefs and threatens their functionality.

For example, high sedimentation rates resulting from coastal development activities such as reclamation or dredging, smothers and buries corals. This increases coral disease, reduces larval settlement and light availability which is necessary for photosynthesis, thereby impacting calcification rates and therefore growth and decline in health.

Ocean warming and acidification are globally recognised as key threats to coral reefs as they contribute immensely to altering the ocean temperature and chemistry. By 2100, global ocean surface temperatures are expected to increase by more than 3 °C. As discussed in Chap. 2, increasing atmospheric concentrations of CO_2 is making the ocean more acidic and making it harder for corals to form calcium carbonate ($CaCO_3$), which is a key building block for them. When carbonate concentrations fall too low, already formed $CaCO_3$ starts to dissolve. Think of it as human bone that has calcium as an essential element. If we pour acid on a human bone, it will start to dissolve. Ocean acidification impacts all marine organisms whose skeleton is made up of calcium carbonate, e.g. all types of shellfish and bivalves such as oysters causing them to have a weak structure that can dissolve or be broken easily.

Increase in sea surface temperatures, or ocean warming, also impacts corals and their symbiosis (i.e. zooxanthellae) as a consequence of coral bleaching events. When seawater becomes too warm, corals need to conserve energy for survival, so it will expel its associated zooxanthellae, as hosting it requires energy. Therefore, the coral will turn completely white once the symbiont is expelled. This phenomenon is called coral bleaching. An increase by 1–2 °C is sufficient for corals to bleach. If temperatures return to normal in a few weeks, then the coral will recover and host its symbiont again. If temperatures do not return to normal for an extended period of time, then the coral will die. Hence, the impact of a coral bleaching event depends on their intensity and severity which can negatively impact coral mortality influencing survival, growth and reproduction. This is alarming, especially when coral bleaching episodes are predicted to increase in frequency and severity, threatening reefs worldwide. The first global mass coral bleaching event which shook the world occurred in 1997–1998 and is recorded as the worst ever witnessed. In 2015–2017, the so-called Godzilla bleaching event severely affected corals worldwide, with the Great Barrier Reef suffering the worst bleaching event recorded, killing an estimated half of its corals.

What Determines the Health of a Coral Reef?

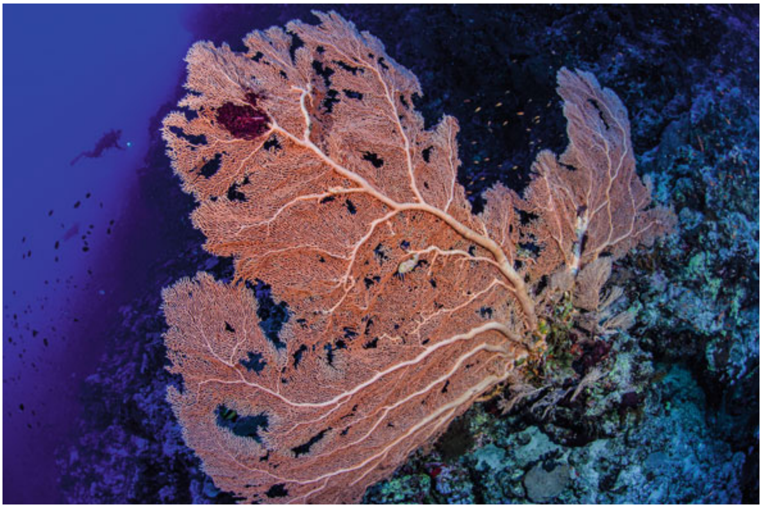
Scientists and reef lovers traditionally determined whether a coral reef is healthy or not by assessing live hard coral coverage and how it changes over time. If hard coral cover is higher than algae, sponges or any other group, then in general the reef is deemed healthy. Conversely, the reef is flagged as unhealthy and considered deteriorating if coral cover continues to decrease over time. In recent years, a new measure to determine reef health, termed "*Reefbudget*," is being adopted by reef scientists. This involves assessing something called a reef carbonate budget. Coral reefs are geomorphic structures built from a calcium carbonate ($CaCO_3$) skeleton. Therefore, if a reef produces more $CaCO_3$ than is eroded, the reef is considered to be in a positive state (healthy). However, if the $CaCO_3$ on a reef erodes faster than is produced, the reef is in a negative state (unhealthy). The balance between $CaCO_3$ production and erosion provides a net figure, the reef carbonate budget, which informs scientists and decision-makers on whether a reef is healthy or not. The *Reefbudget* is important when determining the vulnerability of particular reefs in relation to their ability to keep up with sea level rise. Coral reefs provide islands with stability as they act as barriers therefore protecting coasts from erosion, storms and associated wave action. Thus, it is crucial for reefs to have the ability to keep up with sea level rise. If a positive budgetary state is not maintained and their vertical growth is stunted, reefs will submerge further and ultimately drown due to not being able to access enough light for photosynthesis.

Conservation Efforts

There is collective work being done around the world by scientists, researchers, communities, individuals, governmental and non-governmental organisations, to protect, conserve and restore reefs. The following provides an overview of the various efforts.

1. **Coral Reef Monitoring**
   Coral reef monitoring is an important management and conservation tool. Monitoring is crucial for assessing the status of reefs and the rate of change encountered on a reef (positive or negative). Through monitoring efforts, high-risk areas, including those in need of immediate action, can be identified. In the long run, data derived from reef monitoring programmes are important to better inform decision-makers, reef managers and scientists. It provides an indication of whether the chosen type of conservation effort is effective and fruitful or requires change.

   Unfortunately, many reefs are not monitored on a yearly basis due to the costs involved, e.g. for boats, volunteers, experts and researchers. Nevertheless, some reefs are monitored regularly. Organisations such as Reef Check have developed a standardised technique that can be used worldwide by citizens to monitor reefs thereby encouraging citizen science. The data collected by individuals or organisations can then be submitted to Reef Check who then make it available online. Organisations such as the Global Coral Reef Monitoring Network aggregate data collected by scientists and other groups and produce a status report on coral reefs globally.



Gorgonia Sea Fan—soft coral. *Credit* Hani Bader

2. **Coral Restoration**
   Coral restoration can take on many forms. The type of restoration adopted for reefs is usually defined as either active or passive.

   - **Active coral reef restoration** is dedicated towards enhancing coral reef recovery and health through direct interventions such as increasing coral abundance via for example coral gardening. The aim of active restoration is to restore coral habitats and improve coral reef resilience.
   - **Passive coral reef restoration** aims to create a suitable environment for the restoration and recovery of coral reefs. This includes management strategies such as the creation of Marine Protected Areas (MPAs) and the reduction and/or elimination of known threats such as banning destructive fishing methods.

     In general, passive reef restoration is implemented prior to active reef restoration projects, especially in situ projects (i.e. in the wild). Coral restoration projects can adopt a structural, biological and or environmental/physical approach.
   - **Structural restoration** projects focus on creating the required structural framework for corals and associated organisms to attach to and grow on. This includes the construction of artificial reefs for example through using reef balls or creating wrecks by sinking cars, boats and other structures. This method is usually used in areas where reefs once existed but have lost their framework due to extensive anthropogenic impacts such as dredging, reclamation work or dynamite fishing.
   - **Biological restoration** projects are those that focus on increasing the number of live corals on a reef that has its structural framework intact. This is done through various methods including collecting and reattaching broken coral

fragments from the reef itself, propagating coral colonies, transplanting live coral colonies and or culturing coral larvae. This method is used on reefs whose coral populations have suffered a significant loss and require rehabilitation.
- **Physio-environment restoration** projects are those that focus on providing the right conditions in which corals are planted so that they are able to grow in a manner that would improve their growth rates, overall health and reproductive ability. Much of these types of restoration efforts are still in the experimental stages, for example, the creation of floating and mid-water coral nurseries.

3. **Coral Reef Research and Development**
   Scientists are working on research and development to support reef conservation and restoration efforts worldwide. This includes developing innovative methods and improving current available techniques to enhance the resilience of coral populations, improve coral habitat quality, which in turn will improve reef health and prevent the loss of coral reefs. Scientists are exploring human-assisted evolution which includes a wide range of approaches that aim to enhance selected attributions, for example temperature tolerance in corals, growth and or reproduction, thereby creating resilient reefs. Some of these approaches include coral hybridisation, modification of the zooxanthellae symbiont communities and manipulating various microbial groups, e.g. bacteria that already live inside the coral. Research is a crucial pillar that provides evidence-based direction for the conservation of coral reefs.

In Summary

Coral reefs are of great ecological, economic and recreational value with over 500 million people depending on them for their survival. Despite their importance, the majority of coral reefs worldwide are showing an alarming decreasing trend, which has serious ecological and economic consequences. The world must acknowledge that without substantial reductions in atmospheric carbon emissions, even the best coral reef management and conservation strategies, will not prevent further coral mortalities. Substantial reductions in carbon emissions in combination with conservation efforts could provide future generations with the treasures afforded by this magnificent ecosystem.

Ways to Contribute Towards Conserving Coral Reefs

1. Donate towards coral reef restoration projects and coral research.
2. Reduce your carbon footprint—remember—the more carbon emission, the more we accelerate the rate of climate change which means warmer oceans and more acidic waters.
3. Practice responsible diving and snorkelling when visiting a coral reef.

4. Use reef-friendly sunscreen as research has shown that common sunscreen contains several ingredients, such as oxybenzone and octinoxate, are toxic to coral.
5. Spread the word about coral reefs and adopt a more sustainable lifestyle!

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Reem AlMealla is a nature lover by default, a marine biologist by profession and a climate advocate by concern. She is the first Bahraini woman field ecologist and holds a PhD in Marine Biology from the University of Essex (UK). She was awarded the Abel Imray Award (joint) from the University of Essex for the best outstanding research project of the year 2010 in an ecological based project and the M.E.I (Motivational. Empowering and Inspiring) Women's Award in 2017 by the University of Essex in celebration of International Women's Day.

Reem specialises in coral reef ecology and has over 10 years of field research experience in tropical and sub-tropical environments. Her research interests include reef carbonate budgets, population genetics, utilising nature-based solutions to mitigate and adapt to climate change in addition to environmental policies. Reem deeply believes that for future generations to exist on a healthy planet, it is mandatory for all to cultivate a culture of sustainability and environmental consciousness. When she is not on the field, Reem is a busy bee working on spreading awareness, creating pathways to make data and information freely available in addition to educating the public on the environmental challenges that the world is facing.

Chapter 17
Antarctica and the Southern Ocean: Our Last Great Wilderness

Cassandra Brooks and Claire Christian

The Bottom of the Earth

The Antarctic is often described as a place of superlatives. It is the coldest, driest, and windiest continent, and its land and surrounding Southern Ocean are the most comparatively undisturbed wilderness areas remaining on our planet. For centuries, the region has attracted scientists and explorers eager to unlock its secrets, yet much remains unknown.

From a marine conservation perspective, it can be easy to forget about the Southern Ocean, which is presumably protected by remoteness and harsh conditions. Human activity in the Antarctic marine environment is currently limited to tourism and scientific research and a few commercial fisheries. Thus, the Southern Ocean might seem to be much less in need of urgent attention than other ocean areas, which are threatened by massive overfishing, pollution, mining, and oil and gas extraction. However, Antarctica's ocean is such a vital component of the global ocean, and of the greater earth system, that we cannot afford to overlook it. Moreover, global climate change impacts are compounded in the Antarctic and threaten to unravel the intricately adapted marine ecosystem. Cumulative impacts of climate change, fishing, and tourism are difficult to understand and manage. Securing a healthy planet for future generations requires that we proactively put in place measures to protect the Southern Ocean for the long term, rather than hoping the current status quo will not change.

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While the Southern Ocean is inhospitable to humans, it is a paradise for marine life, all superbly adapted to its frigid environment. Huge swarms of Antarctic krill (*Euphausia superba*), a small shrimp-like crustacean, form the basis of the food web in the Antarctic and support thriving populations of species ranging from a fifty-armed sun star (*Labidiaster annulatus*) to huge humpback whales (*Megaptera novaeangliae*), along with many species of everyone's favorite tuxedo-wearing penguins, of course. In a true victory for the ecosystem, the populations of most of the seal and some whale species formerly put at risk of extinction by exploitation in the nineteenth and twentieth centuries have stabilized and even increased in the Southern Ocean. Tourists to the region are instructed to avoid disturbing even a single penguin, as they are guests in a place that still belongs to this rich array of wildlife.

Beyond the charismatic seals, penguins and whales, the Southern Ocean has rich underwater biodiversity rivaling that found in warmer areas, including fish with antifreeze proteins in their blood and cold-water coral that can move across the ocean floor to find food. We know very little about many of these species, and consequently, the study of Antarctica's biodiversity lags behind that of other regions. Many scientists consider Antarctica an ideal natural laboratory to study healthy marine ecosystems with minimal human-induced disturbance, very few of which remain in existence.

Antarctica's rich and diverse wildlife. *Credit* John B. Weller

Threats to the Antarctic

Although Antarctica is remote, fishing, tourism, and scientific research all take place there. Since the Antarctic environment is fragile and less resilient to disturbance, even low levels of these activities may cause significant harm. For example, pollution created by scientific research stations decades ago is still detectable in nearby coastal waters.

Fishing primarily takes place for two species, toothfish (also known as Chilean sea bass) and krill. Toothfish is a high-value species that often sells for as much as $30/pound, while krill is primarily used for omega-3 nutritional supplements and feed for farmed fish. Fishing activities in the Southern Ocean are dangerous due to weather conditions and expensive due to fuel and other logistical requirements. As with other fishing on the high seas, Antarctic fishing does not significantly contribute to global food security. There is some illegal, unreported, and unregulated (IUU) fishing, but fortunately this has declined since the early 2000s.

Like fishing, Antarctic tourism is expensive, but is a growing industry. In 2018–2019, 56,168 tourists visited the Antarctic according to the International Association of Antarctica Tour Operators (IAATO). Prior to the coronavirus pandemic, it was estimated that Antarctic tourism would increase by about 40% in under a decade due to a number of new ships entering the market. While this may seem small compared to other tourist destinations, most visits to Antarctica take place at a relatively small number of ice-free sites in the Antarctic Peninsula, and thus are not evenly distributed around the continent. Most of the guidelines and rules that tourists currently follow are for the most part voluntary. Right now, the industry is largely willing to abide by these guidelines, but this may change.

With the human presence also comes various forms of pollution. Any ship, whether tourist, research, or fishing vessel, burns fuel and therefore produces pollution. Although air travel is more limited, it also produces pollution. Disposal of human waste and wastewater has also contaminated the Antarctic environment. One emerging source of pollution that is of particular concern is plastic and especially microplastic pollution. The primary local source of this is through laundry water (often called greywater) due to the high number of warm weather clothes that are made of synthetic, plastic-based fabrics. Microplastic pollution has been detected in the Southern Ocean and is known to be concentrated near research stations. Some vessels have begun to install filters to prevent these particles from being discharged into the ocean, but this is not yet a universal practice.

Antarctica's Role in Global Climate

Antarctica plays a critical role in global climate and ocean circulation processes. One example of this is the formation of Antarctic Bottom Water (AABW). When ice forms on the surface of the Southern Ocean during winter, much of the natural salt in seawater is excluded from the ice. The resulting saltier water sinks down below surface layers and subsequently circulates throughout the globe, carrying vital nutrients to other ecosystems. Increased melting of ice sheets and glaciers due to global warming may make AABW less salty, with expected far-reaching consequences for ecosystems. This melting also contributes dramatically to global sea level rise since Antarctica stores the majority of the world's freshwater. If all of Antarctica's ice melted, it would raise sea levels over 200 feet (about 60 m). Scientists are also revealing that Antarctic krill plays a key role in ocean biogeochemical cycles, drawing into question the greater impacts of the growing fishery for krill. And among the melting ice, krill and the entire Antarctic system are struggling to adapt.

In recent years, it has become increasingly clear that the Southern Ocean is affected by local and global human activities. We can no longer assume that the Antarctic is safe because it is far away and has no permanent inhabitants. Global climate change has already begun to affect the continent and its surrounding ocean in measurable and alarming ways. Moreover, local human pressures continue to increase as well, potentially magnifying climate-related stress on ecosystems and species. In much the same way that addressing global climate change requires collective action at local, national, and international levels, protecting Antarctica will require global commitments. For the Southern Ocean, these actions lean on an international, treaty-based organization called the Commission for the Conservation of Antarctic Marine Living Resources (hereafter, The Commission).

Antarctic Governance: Peace, Protection, and Science

The Commission was formed in 1982 after the signing of a major international treaty known as the Convention on the Conservation of Antarctic Marine Living Resources. The Convention is part of the Antarctic Treaty System, a series of treaties establishing an international system of governance for Antarctica that was created in 1959 with the ratification of the Antarctic Treaty. Signed at the height of the Cold War by 12 countries including the U.S.S.R and the U.S., the Antarctic Treaty was a tremendous accomplishment in international cooperation, establishing that Antarctica would be an international commons. The Antarctic Treaty bans military, nuclear, and mining activities while granting freedom of science and declaring "Antarctica a nature reserve, devoted to peace and science."

As fishing for krill began to increase in the Southern Ocean, the countries party to the Antarctic Treaty became concerned that additional measures were needed to protect marine ecosystems.

Thus, they negotiated a new treaty, which is known as the Convention on the Conservation of Marine Living Resources (hereafter, The Convention).

The Convention enshrines conservation as the main objective of the agreement although fishing is permitted as long as it meets three key principles:

- It does not harm the ability of the fished species to reproduce and maintain population levels.
- It does not interfere with ecosystem relationships.
- It does not cause changes to the ecosystem that cannot be reversed in two or three decades.

These simple principles of the Convention, which today are carried forward by a 26 member multilateral Commission, demand a precautionary, scientifically grounded, ecosystem-based approach to the management of activities, including fishing. At the time, these principles were revolutionary, representing a shift away from traditional fisheries management, which focuses primarily on one species at a time and is much less concerned with precaution. Even so, we now know that these principles are not sufficient for the long-term preservation of marine environments. Therefore, to safeguard biodiversity amidst climate change and emerging fisheries, the Commission has been working toward implementing a Southern Ocean network of marine protected areas (MPAs).

In 2002, the Commission began discussing how to contribute to a global network of marine protected areas (MPAs), following a commitment by many nations at the World Summit on Sustainable Development to establish representative networks of MPAs by 2012. The Commission formalized their commitment to establishing a system of MPAs in 2009 by 2012. As discussed in Chap. 21, extensive research supports that MPAs—areas where fishing and other human activities are restricted—can conserve biodiversity, and perhaps most importantly in the case of the Southern Ocean, can enhance resilience to climate change impacts. By 2005, the Commission began working toward identifying priority areas for protection and compiling the best available science to guide development of an ecologically representative network of Southern Ocean MPAs. In 2009, the Commission adopted its first MPA south of the South Orkneys Islands which protects ~94,000 km^2 as a no-take reserve. In 2011, the Commission adopted a framework to guide the MPA process and individual member countries began developing MPA proposals in their historic regions of interest.

In 2016, the Commission made history by adopting one of the world's largest MPAs in the Ross Sea, Antarctica, conserving about 2 million km^2 with over 70% being fully off-limits to fishing. Currently, there are three MPAs still under negotiation, including in the Weddell Sea, East Antarctic, and the Western Antarctic Peninsula—all of which would contribute to a representative network of Southern Ocean protected areas. Yet, all three of these proposals have not yet been adopted largely due to political barriers, economic interests, and some countries' efforts to re-interpret the Convention as meaning that fishing is part of conservation and therefore cannot be significantly restricted. This is of course contrary to the precautionary approach and even contrary to the Convention, which clearly states that areas may be closed to fishing. These efforts are a troubling sign that long-standing international norms are being reversed, and Antarctica is being subjected to the same narrow thinking that has led to massive environmental destruction elsewhere. Even efforts to incorporate climate change into the Convention decision rules have been hindered.

Despite the progress in declaring two MPAs and proposing several more, the Commission is still a long way from delivering on their commitment. Their deadline has passed by almost a decade (as of this writing) even as many leaders are urging significant action on conservation. Further delay in protecting the Southern Ocean jeopardizes the ecological integrity of this fragile yet essential part of our planet.

Cassandra Brooks—Personal Account

In the 15 years that I have been going to and studying Antarctica, I have witnessed dramatic changes. Regions of the Antarctic Peninsula in particular have experienced significant warming. This warming is causing an estimated almost 90% of glaciers in the region to retreat, multiple ice shelves to collapse, reductions in seasonal sea ice, and unpredictable shifts in marine ecosystems as species struggle to adapt.

Perhaps, most unsettling (to me, as I named my very children after Antarctic wildlife) was to see how Adélie penguins, my daughter's namesake, had almost completely disappeared from the region. These penguins depend on colder temperatures, and thus have moved south, with other penguin species taking over their nests. Let me elaborate further the significance of this shift.

Adélie penguins nest on the few small patches of ice-free rocky land throughout Antarctica. They build nests using pebbles—precious pebbles which are relatively difficult to find in this icy landscape. They spend tremendous energy collecting and rearranging these pebbles into nests. Every nesting season, the Adélies come back to their nests which they tenderly built the previous season. And this ritual has been carried out for thousands of years in some colonies. To witness the abandonment of some breeding sites in a matter of years is a dramatic change to say the least. Adélie penguins are moving south, but as the south warms, they will have nowhere else to go. In my daughter Adelie's lifetime, she may see the disappearance, and most certainly, a drastic reduction of the species that is her namesake.

All that I witnessed is supported by robust science, and it is not just remote polar animals that will suffer. Over the last thirty years, the International Panel on Climate Change (IPCC), a UN body tasked with understanding climate change, has released dozens of reports, all reconfirming, with ever more science, the state of our changing planet. But, the message embodied in the 2020 IPCC report, one focused on the oceans and cryosphere (the world's ice systems), is the most bold and urgent message to date: If we do not act with urgency to protect our oceans and cryosphere—including the Antarctic, we—and the future generations—will suffer greatly. We know protected areas work to safeguard biodiversity and ecosystems. We must demand action toward healthy oceans now.

Credit Matthew Kemp/Greenpeace

What You Can Do to Help Antarctica

The Commission must do better. Climate change—along with a global crisis of biodiversity loss—is here, and MPAs are our best tool to give Southern Ocean species a chance of enduring into the future. Antarctica stands as a profound example of what is possible when humans put aside short-term economic interests and politics and concentrate on long-term goals of conservation. At one time, the thought of banning mining in Antarctica was considered ridiculous and unrealistic. No one would ever agree to put aside potential wealth to protect penguins. Today, nations proudly boast of their role in doing just that. We now need to reignite this same spirit and willingness to dream big, both for the Southern Ocean and for the world. You can help make that happen.

While many of the decisions about Antarctica and the Southern Ocean are made in formal diplomatic conferences not open to the public, you can still let your government know that you support MPAs in Antarctica. Too often, international decisions, whether on climate change or high seas protection, are made without public input. World leaders need to know that the world is watching the decisions they make about our last great wilderness, and that we expect that they will live up to their promises to keep the Southern Ocean thriving.

You can also engage with environmental organizations interested in the protection of Antarctica on social media to learn more about the issues and to stay informed about opportunities to promote conservation. The Antarctic and Southern Ocean Coalition (ASOC) has member organizations, some of which may be local and have activities in your area. Even engaging on local and national environmental issues can be important. The biggest threat to Antarctica is global climate change, and every nation on the planet must take immediate, bold action to reduce this threat.

Whether you fight for Antarctica by holding your city's leaders accountable to their promises to reduce carbon emissions, or by telling your leaders to put Antarctica's ecosystems first and create MPAs, you are making a difference. We must change pessimistic policies and narratives that tell us that it is too difficult to establish a relationship with the natural world that preserves rather than depletes. We have done this in Antarctica before, and we can rise to the challenge again.

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Dr. Cassandra Brooks is an Assistant Professor in Environmental Studies at the University of Colorado Boulder. She has a fierce passion for Antarctica, with the last fifteen years of her career focused on marine science and conservation in the region. This passion began when she was a Master's student studying life history of the Antarctic toothfish in the Ross Sea, a population that supports the most remote fishery on Earth. She then turned to media and advocacy as a core member of The Last Ocean, a grand-scale media project focused on protecting the Ross Sea, Antarctica. Along the way, she pursued expertise in the policy realm, completing a Ph.D. studying marine protection in the Antarctic. Cassandra worked alongside a global community of scientists, policy-makers, conservation groups, and public citizens (including Claire Christian) to drive the adoption of the world's largest marine protected area in the Ross Sea, Antarctica in 2016. Cassandra is immensely proud of this work, and it brought her to her husband—conservation photographer John Weller—and their two children, who are named after Antarctic wildlife.

Claire Christian is the Executive Director of the Antarctic and Southern Ocean Coalition (ASOC), an organization focused on the conservation of the Antarctic. Though she entered the world of Antarctica by chance while searching for a part-time job during graduate school, she quickly developed a deep appreciation for the region. She was inspired by the opportunity Antarctica offers for us to learn from past mistakes and pursue a path of precautionary protection of the natural world. A firm believer that the Antarctic wilderness belongs to all of humanity, she is also committed to ensuring that the countries that govern Antarctica live up to their obligation to preserve the region. Claire has a special fondness for Antarctica's fascinating but little-known invertebrate species, and aspires to make them as famous and beloved as penguins.

Chapter 18
Top of the World—The Arctic Ocean

Malgorzata Smieszek

Arctic Ocean

The Arctic Ocean is the world's smallest ocean, and the northernmost body of water on Earth, situated entirely above the Arctic Circle—a line of latitude that defines the Arctic region. The Arctic, much like Antarctica, has long caught people's imagination and desire for exploration. Even today, many people still envision the Arctic as a pristine, intact, frozen area covered with snow and ice. Perhaps because of the ice, many imagine it as land—even though the heart of the Arctic is actually the Arctic Ocean. In fact, although many people think of the Arctic and Antarctica as similar, the two are almost geographic opposites. The Antarctic is a continent surrounded by the ocean, and the Arctic is an almost land-locked sea, nearly completely surrounded by the landmasses of North America, Eurasia, and Greenland, and territories of five Arctic states: Canada, Denmark (via Greenland), Norway, Russia, and the United States via Alaska.

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The Arctic Ocean is connected to the Atlantic through the waters of the Barents and Kara seas, the deep channel of Fram Strait between Svalbard and Greenland, waters of Baffin Bay and Davis Strait, and the narrow straits of the Canadian Arctic Archipelago. Through the narrow passage of the Bering Strait between Russia and the United States, the Arctic Ocean interacts with the North Pacific, ultimately forming a direct link between the Pacific and Atlantic oceans, and providing the shortest sea route between them.

The Arctic Ocean and some of its coastal seas, among them the Beaufort Sea, Chukchi Sea, Kara Sea, and Laptev Sea, are the least known and explored bodies of water in the world. The primary reasons behind this are their remoteness, the harsh conditions of the cold climate, darkness for up to six months each year, and the seasonal and perennial (multiyear) sea-ice cover, which is the most notable characteristic of the Arctic.

This distinctive characteristic—Arctic sea-ice—is today receding at an alarming and unprecedented rate.

The Decline of Arctic Sea-Ice

The Arctic Ocean is experiencing some of the world's most dramatic warming from human-induced climate change. Historically, sea-ice covered about half of the Arctic Ocean. With the onset of the satellite era in the 1970s, it became possible for scientists to conduct observations and obtain measurements of Arctic sea-ice. We now know that over the last 50 years, between 1979 and 2019, the extent of Arctic sea-ice in September, when the ice-covered area reaches its annual minimum extent, has decreased by 44%. The sea-ice in the Arctic is also becoming thinner, meaning that what was once multiyear thick ice cover, surviving more than one season, is presently turning into younger, thinner, and seasonal ice coverage. In 2019, the Intergovernmental Panel on Climate Change (IPCC), the world's primary body which evaluates climate change science, confirmed that over the last fifty years we have lost close to 90% of multiyear sea-ice that would be at least five years old. It is this ice that will not recover in our lifetimes.

As the Arctic region, both at sea and on land, continues to change at a rapid and accelerating pace, we scramble to keep up our understanding and account of that change. News about Arctic climate comes today with a frequency one would associate with seasonal weather patterns, not with the climate that, by default, relates to longer periods of time, and which has been remarkably stable over the last 10,000 years of our planet's history. Still, in May 2021, the Arctic Monitoring and Assessment Program (AMAP), one of the working groups of the Arctic Council, a primary intergovernmental body for Arctic collaboration, reported that over the last fifty years, the Arctic has warmed up not two times more than the rest of the globe, as it was previously assessed, but three times more. The pace of that change is accelerating as well: 0.75 °C of Arctic warming has happened in the last decade, much more than the global average. The largest increase in air temperature was noted over the Arctic

Ocean, where it averaged 4.6 °C—and where the peak reached 10.6 °C over the northeastern parts of the Barents Sea. A study published a month later, in June 2021, found that sea-ice in the Arctic coastal seas is thinning twice as fast as previously thought. Thinner Arctic sea-ice is more vulnerable and fragile; it breaks more easily, and it melts faster in the summer, leaving more open waters in the late summers and early fall across the Arctic. It also allows more sunlight to reach the ocean water below it, which further contributes to Arctic warming.

Globally, the ocean is the largest collector of solar energy, which gives it a central role in the Earth's climate system. Arctic sea-ice plays an essential role in maintaining the planet's temperature and acts as a refrigerator for the northern hemisphere. Its white surface reflects 50–70% of sunlight that otherwise would be absorbed by dark ocean waters. With sea-ice receding, larger and larger swaths of the Arctic Ocean become exposed to solar energy/radiation, absorbing heat that consequently prevents sea-ice from recovering, and further magnifies Arctic warming. It is a phenomenon that scientists call "Arctic amplification". While there are a number of factors that contribute to this amplification, the loss of Arctic sea-ice caused by human-driven climate change plays a critical role in this feedback loop and drives a self-perpetuating process. According to scientists, Arctic summer sea-ice could disappear entirely as early as 2035.

Svalbard. *Credit* Esther Horvath

Arctic Wildlife at Risk

It is not only global climate that depends on Arctic sea-ice, but also many species that rely on ice as their habitat. They include some of the iconic Arctic animals such as polar bears, ringed and bearded seals, and walrus. For polar bears, earlier break-up of sea-ice in the spring means bears have less time for hunting seals on the ice, which, in turn, affects their body condition and decreases their chances for reproduction and survival. Walrus not only mate and give birth on sea-ice, they use it to rest offshore, allowing them to stay closer to feeding grounds that otherwise would be out of their reach. As the sea-ice in the Arctic thins and recedes much earlier than it used to, it restrains the walrus's access to abundant food sources offshore and forces them onto land, where female walruses might have difficulties nourishing their young.

Along with polar bears and seals, many Arctic Indigenous communities are affected by changes in the sea-ice and the impact this has on species they harvest. The importance of sea-ice for Indigenous communities, however, goes far beyond economic and subsistence activities and providing grounds for traveling. As reflected in the language of the Inuit, Indigenous Peoples of Alaska, northern Canada, Greenland, and Chukotka (Russia), sea-ice is at the core of the culture, environment, and spirituality of Arctic coastal Indigenous Peoples, and their societies depend on it. Although decrease of sea-ice might bring new and expanded economic opportunities to Arctic communities, the cumulative effects of these activities and stressors they add for Arctic fauna and flora need to be considered as well.

Ultimately, humans are a part of the Arctic ecosystem, and marine microbes, plants, animals, and humans that rely on them, form an intricately interconnected food web. At the base of this web are primary producers, oftentimes single-celled algae that live in the ice or in the water. These primary producers capture energy from sunlight reaching the Arctic to nourish themselves and, effectively, support all other forms of marine life. Since the sea-ice and snow cover on ice reduce the amount of light reaching these producers at the base of a food web, sea-ice is an important factor in determining the presence and abundance of Arctic species. Yet, its importance goes well beyond the seasonal cycles of light availability. Distribution, characteristics, and timing of Arctic sea-ice affect most of the conditions underlying Arctic marine ecosystems, for example, the temperature of the water, flow of nutrients and energy, and their exchange between the ocean bottom and open water. As the changes we observe unfold at a pace that is too fast for evolutionary adaptation, many Arctic species—including the human populations who rely on them—become more vulnerable and their future uncertain.

Global Consequences of a New State of the Arctic Ocean

The changes unfolding in the Arctic Ocean carry great weight for the whole planet. Even though, most people will never see with their own eyes this smallest of the world's oceans, many will be affected by the Arctic Ocean, whose waters are becoming more open, warmer, and are receiving increased volumes of freshwater from melting sea-ice including from the major rivers of Alaska, Canada, and Russia.

We hardly think about the vast role that global ocean circulation plays in our lives and societies. The Arctic Ocean is a vital part of that system, and as it carries more and more freshwater into the North Atlantic, it disturbs circulation currents of the Atlantic that are key to the global climate system and oceanic circulation patterns. There is evidence that Arctic warming is connected to weather patterns at midlatitudes, including heightened likelihood of extreme weather events, such as droughts, floods, heat waves, and battering spells of extreme cold, as those experienced in the last years in many parts of Canada, Europe, and the United States.

Recent studies tell us that Arctic warming is locked into the system for the coming decades and, even if parties to the Paris Agreement deliver on their existing commitments, winter temperatures over the Arctic Ocean will still increase 3–5 °C by 2050 compared to average temperatures in the period 1986–2005. It does not mean, however, that it should temper our efforts to cut emissions of greenhouse gases as rapidly as possible. To the contrary, it should be the impetus to double down on our actions to achieve zero carbon societies and economies as fast as possible. To illustrate that, there is a world of difference whether we manage to keep global warming below the Paris Agreement's aspirational goal of 1.5 °C, or whether we reach 2 °C temperature rise above pre-industrial levels, not mentioning going beyond them. For the Arctic Ocean, that half a degree means 10 times greater likelihood of summers free from any sea-ice coverage, and a transition to an entirely new climate and state compared to the one we have known.

During polar nights, the only light came from the headlamps of the expedition participants and from the ship Polarstern. In the heavy wind you could not hear anything and in the darkness you could only see in the spotlight of the ship, everything in the shadow remained invisible.Central Arctic Ocean. *Credit* Esther Horvath

Esther Horvath—Polar Science Photographer—Personal Account

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Credit Harold Jager

I am a professional photographer, member of The Photo Society, a collective of National Geographic photographers; a member of The Explorers Club; Fellow of the International League of Conservation Photographers, and a photographer for the Alfred Wegener Institute (AWI) in Germany. Since 2015, I have dedicated my photography to the Polar Regions, where I want to show the full research story behind our climate data, following the work of multiple scientific groups that are working to better understand the changing poles.

My love story with the Arctic Ocean began in 2015 when I first traveled to the land of seemingly infinite ice on board US Coast Guard icebreaker *Healy*. It was an assignment from Sabine Meyer at the *Audubon* magazine, and I did not know this journey would change my life forever. Standing on the bridge of the ship, spending sleepless nights, I was mesmerized by the beauty of the Arctic Ocean sea-ice, and of this ever-changing landscape. I did not want to waste any time sleeping as I was only there for two weeks. For the first time, I wanted to take everything in, like a hungry child pushing food into her mouth without knowing when to stop. The more I looked at the sea-ice, the hungrier I was to learn about it.

During that trip, I decided that I want to dedicate my photography to the Arctic Ocean and work with scientists. Who are the scientists who deliver important climate data for us, how do they live and work in this harsh environment? How do we come to know that average temperatures in the Arctic rise two to three times faster than everywhere else on the planet? I wanted to tell the story of the Arctic Ocean through the work and life of the scientists who dedicate themselves to understanding this region. My love story continues after thirteen scientific expeditions to the Arctic.

In planetary terms, the Arctic Ocean serves as an air-conditioner, regulating the weather and global climate. The more the Arctic changes, the more changes we will feel in our lives. It is important to differentiate the sea-ice and the ice-covered Greenland with its ice sheet. If the sea-ice melts, it will not increase the sea level because the ice is already in the water. We know this from the Archimedes principle. At the same time, if the sea-ice goes, and with it, its capacity to reflect sunlight, our planet will warm at a higher speed.

Every time I travel to the Arctic, I feel I might be photographing a landscape which will never be the same again. I feel a responsibility to capture the moment of our changing natural history and with that to raise awareness about this fragile environment. I hope my images have that effect. With my images, I hope the viewer connects to the Arctic the way I do.

In 2019–2022, I was honored to take part in the MOSAiC expedition, which was the largest Arctic Ocean expedition in history. Together with hundreds of scientists from 20 countries, we spent months in the polar night, collecting baseline knowledge, which will be used for decades to come. During that time, I reflected on the disappearing sea-ice, and how—once it is gone—we will sail to the North Pole, lamenting the landscape that will be altered and gone forever. I hope I will never have to experience this. I want to walk on the sea-ice and be afraid of polar bears that call the Arctic their home, together with many life forms living in this frigid environment. Connecting to the Arctic Ocean is easy through polar bears, but we cannot forget all other species in the food chain, starting with the smallest copepods, zooplanktons, which are the starting point of this blooming landscape. If the sea-ice melts, the very foundation of life here will be gone.

Our window to save this precious environment is closing. The Arctic Ocean is the most beautiful landscape I have ever seen, with its constantly changing and moving sea-ice. The extreme light during the midnight sun to the complete lack of light as polar nights arrive. There is no place like it. A land with no ground—a land made of water. This land exists only if the water remains frozen.

As Goes the Arctic, So Goes the World

The state of the Arctic Ocean today is a palpable reflection of most problems we see in other parts of the world. As described, the region is a harbinger of global climate change and of the unprecedented, destabilizing, and accelerating transformation we are putting our ecosystems, and our communities and societies, through. Concurrently, even as new studies confirm and bring new, more accurate and dire assessments of the state of the Arctic, there are ongoing and intensifying discussions about new economic and industrial activities enabled by the opening of the Arctic Ocean. The northern waters, both along the coasts of Russia and North America, as well as across the North Pole, represent the shortest distance between Europe and North America and between Europe and the East Asian harbors. There is surging interest in shipping in the Arctic, as well as in exploring and exploiting new reserves of oil and gas that can be found in the Arctic, despite the scientific consensus that, if we are to have a fighting chance to limit the most devastating effects of global climate change, all fossil fuels need to stay in the ground. As the waters are warming and fish are migrating northward, there are discussions about expanding fisheries in the North although it is recognized that short-term gains related to it will have major consequences for the rest of the ecosystem. Like everywhere in the world, plastic litter is found today on Arctic beaches, in Arctic waters, and even in the bodies of Arctic birds and mammals, accumulating and negatively affecting the environment, food systems, and communities that rely on them.

It does not have to be this way. The state and dramatic changes to the Arctic and Arctic Ocean give us a chance to pause and reflect where we want to go from here. As prospects for new economic developments drive interest and lure more actors into the region, do we dare to imagine a different world, where rather than walking the same path we have in the past, we base our actions on the respect for nature and on the acknowledgement of an intricate web of connections that we, humans, are an intrinsic part of? Are we able to put in place fast enough effective ecosystem-based management systems, rather than addressing emerging issues in compartmentalized, piecemeal fashion, where we focus on individual issues and sectors, but we continuously miss the larger picture?

While there are many things we do not know and understand about complex linkages between the Arctic Ocean, atmosphere, the region's ecosystems and global climate change, we know more than enough to take action.

The change we see unfolding in front of our eyes in the Arctic Ocean is a result of human activities, primarily outside of the Arctic. Both the unprecedented melting of Arctic sea-ice and plastics brought to Arctic shores have their origins in mid- and southern latitudes and in our actions. Whereas a major systemic transformation and overhaul is needed to adequately respond to the scale of the grand challenge of global climate change, actions we all take in our everyday lives do matter.

Every time we get into a car or on a plane, we produce carbon dioxide, a big part of which will stay in the atmosphere for 500 years or more, contributing to warming of the Arctic and of our planet. As eloquently and movingly written by Kimberly

Nicholas in her book "Under the Sky We Make," our carbon footprint is the one thing that we will share, no matter what, with dozens of future generations to come. The carbon dioxide we add to the atmosphere today will outlast us all and take up all the limited remaining part of the carbon budget that is left for the whole world, both humans and nature, today and in the next hundreds of years. For this reason, every single action we take to cut our carbon emissions matters. This includes our use of plastic, which is not only produced with vast amounts of fossil fuels, but also takes between 20 to 500 years to decompose. While the carbon dioxide we emit might seem more elusive and invisible, pictures of plastic litter on the farthest ends of the planet, including in the Arctic Ocean, serve as the potent illustration of the impact and reach we, as humans, have on the rest of the world. Even though we might feel that the Arctic and the Arctic Ocean are far from us, we are intimately connected to them and what we do bears an impact on their future. As goes the Arctic and the Arctic Ocean, so goes the world. The future of the Arctic Ocean is a matter of the choices we make.

Arctic sea-ice during the polar night. *Credit* Esther Horvath

Malgorzata Smieszek In my research, I study the effectiveness of international environmental governance, with a particular focus on the Arctic, where I try to understand what makes international environmental institutions effective and how their performance can be improved. What drives me in my work is the deepest respect and reverence for nature and the wonder of life on our planet. While we observe vast changes in the environment around us and in all corners of the globe, and every day we learn more about the intricate connections that sustain a web of life on Earth, the sheer understanding of these phenomena is not sufficient to stop the destruction of the planet we are causing. Ultimately, nature needs no change—it is doing everything as it is supposed to. It is us humans, our societies, and the institutions we design and create that need to change and alter those actions that send into disarray the world's climate and majestic biodiversity. We need to urgently correct the course we are presently on, polluting and pushing to the edge of collapse and extinction the very systems on which life on Earth—and our life with it—depends. This goal—and the tiniest contribution I can make to achieve it—is what drives me and sustains my passion for my work (*Credit* Marko Junttila).

Chapter 19
Coastal Habitats

Lauren V. Weatherdon

Introduction

Coastal habitats are amongst the jewels of the ocean, connecting life on land with the nutrient-rich waters of the ocean. For many people, rocky shorelines and coastal wetlands such as saltmarshes, seagrasses and mangroves are doorways to the extraordinary beauty of the ocean and its biodiversity. Unlike the difficult-to-access wonders of the deep sea, coastal habitats bring enjoyment to tourists as well as food, cultural and economic security to coastal communities around the world. With more than 2.4 billion people living within 100 kilometres of the coast and a demand for food that is outpacing global population growth, healthy coastal ecosystems are more important than ever for ensuring sustainable and healthy communities.

Healthy coastal ecosystems contribute greatly towards many environmental, climate and sustainable development agendas set by the international community. For example, as discussed in Chap. 3, many 'blue carbon' ecosystems such as seagrasses, saltmarshes and mangroves have been shown to play an important role in sequestering and storing carbon, helping countries to progress towards the carbon reduction commitments of the Paris Agreement that are essential to our collective well-being.

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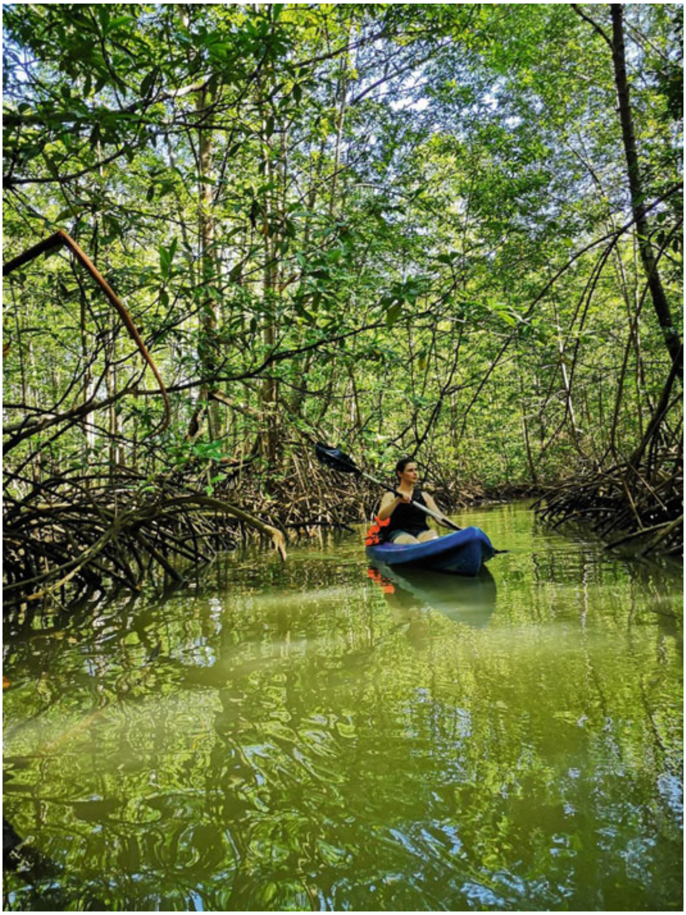

Mangrove forests near Manuel Antonio National Park, Costa Rica. *Credit* Lauren Weatherdon

A Silent Decline in Coastal Habitats

Scientists have noted that we know more about the Moon, Venus and Mars than about the global ocean here on Earth. Whilst the ocean covers 71% of our planet, only around 15% of the ocean floor has been mapped at a high resolution.

Surprisingly, we also have a limited knowledge of coastal habitats, which has critical implications for how we manage these important ecosystems. Although estimates vary depending on data availability and the 'baseline'—or starting point—we refer to, scientists have documented the loss of nearly 50% of coastal wetlands around the world over the past century. This is due to a combination of localised human pressures, sea-level rise, warming and extreme climate events, with anywhere between 20 and 90% of remaining wetlands projected to be lost by 2100.

Whilst these habitats are on our doorstep, consistent and standardised mapping and monitoring of them is still rare and is seldom curated at regional or global scales. Those who have worked with data will recognise the funding and work this requires: most research time is spent collecting, processing and managing data to ensure they are fit for purpose. This challenge is compounded by scale, where data collected in different locations in different ways and at different times must be brought together into harmonised databases. The accessible yet often uncharted nature of these habitats also makes them vulnerable: they are not only at the forefront of peoples' minds but also frequently at the frontline of development decisions. When placed in direct opposition with opportunities for economic growth and local job creation—such as a growing tourism industry that benefits from oceanfront hotels or lucrative resource extraction that requires access points through critical habitats—the economic and job argument often wins.

Coastal habitats represent a connected gradient rather than a clear boundary between land and sea. Coral reefs, seagrasses, mangroves, kelp forests and other habitats often form interconnected 'mosaics' of multiple habitats that together provide the structures necessary to protect coastal populations from storm surges. Moreover, they provide nurseries for fish and invertebrates that are critical for feeding local communities or feeding or breeding sites for migrating birds and marine mammals. Research has highlighted this connectivity of land and sea, with many of the threats facing coastal habitats originating from land. Nutrient run-off from agriculture or other industrial activities and plastic pollution are amongst these threats, with between 1.15 and 2.41 million tonnes of plastic estimated to enter the ocean each year from rivers. Microplastic (small plastics less than 5 mm in length) and plastic debris in particular also pose threats to associated species, such as sea turtles and seabirds.

Despite coastal community efforts to mitigate and adapt to climate change by protecting coastlines, coastal habitats are equally at risk from a changing climate. Whilst large-scale coral bleaching is increasingly featured in the news, changes in ocean temperatures and salinity combined with sea-level rise are also affecting the health of mangroves and seagrasses and are altering coastlines through increased erosion of cliff faces. Where there are no barriers to doing so (e.g. coastal cities and infrastructure), coastal wetlands such as mangroves are increasingly projected to move landward in response to sea-level rise to avoid 'drowning'.

Together, these threats have a cumulative impact on the health of coastal habitats and their ability to sustain the flora and fauna we depend on for our well-being.

Coastal erosion in Covehithe, Suffolk, UK. *Credit* Lauren Weatherdon

A Global Response

Protection of coastal habitats is of international concern. Benefits include those at the community level, such as contributions to local livelihoods. Internationally, benefits include regulated climate, reduced risks from natural disasters, and scaled contributions to global food and economic security derived from healthy coastal ecosystems.

Parties to several multilateral environmental agreements have recognised the importance of marine and coastal habitats and the biodiversity they support to our collective well-being. Examples include:

- the Convention on Biological Diversity and its emerging post-2020 global biodiversity framework,
- the UN Framework Convention on Climate Change (UNFCCC) and the associated Paris Agreement, and
- the Convention on International Trade of Endangered Species of Wild Fauna and Flora (CITES).

In 2015, all UN Member States adopted a set of 17 international Sustainable Development Goals (SDGs) and 169 associated targets of the 2030 Agenda for Sustainable

Development, intended to transform the world through an ambitious global plan to end poverty, protect the planet and improve the lives and prospects of everyone.

Coastal ecosystems have been recognised as crucial to the achievement of these targets through their 'ecosystem services'—a term that describes their direct and indirect contributions to human well-being. Coastal habitats:

- supply the natural resources needed for local food security (SDG 2, 'Zero hunger'),
- support life on land and at sea (SDGs 14 and 15, 'Ocean and terrestrial ecosystems'),
- underpin local jobs through tourism and sustainable resource use that contribute to a higher quality of living for communities (SDG 8, 'Decent work and economic growth' and SDG 1, 'No poverty') and
- provide protection for coastal infrastructure from storms (SDG 11, 'Sustainable cities and communities').

Access to intertidal ecosystems has also been shown to have benefits for equality: many women and children harvest or 'glean' fish, invertebrates and kelp from the shoreline as part of informal economies that feed local communities and generate income (SDG 10, 'Reduce inequality').

In fact, more than 2 billion people around the world—or more than 61% of the global employed population—are estimated to be a part of informal economies such as these, which often depend on healthy ecosystems for small-scale agriculture and fisheries.

Monumental efforts are now also underway to document these important ecosystems, harnessing satellite imagery and acoustic mapping technologies to produce high-resolution snapshots of their location and condition.

A Deeper Dive: Seagrasses

An estimated one billion people live within 100 kilometres of seagrass meadows, which are found in 159 countries on six continents around the world.

As highlighted in a recent global synthesis report, seagrass meadows offer often overlooked contributions to human well-being, from nursery grounds for commercially valuable fish stocks and storage of up to 18% of the world's oceanic carbon. They also host culturally important and charismatic megafauna such as dugongs and sea turtles.

Despite being found in many places around the world, the health of seagrasses globally is at risk, with growing fragmentation and declines in seagrass meadow health and resilience. To date, at least, 22 of the world's 72 seagrass species are in decline, with almost 30% of seagrass meadows having been lost since the late nineteenth century. Seagrasses depend on good water quality and were therefore adopted as a biological quality element or indicator of water quality within the EU Water Framework Directive (2000/60/EC).

Seagrass ecosystem resilience can be strengthened by many management measures, including providing sufficient seed banks, improving water quality, balancing food webs, supporting connectivity between seagrass meadows and reducing cumulative pressures.

Solutions and Actions We Can Take

Regardless of your career or hobbies, there are many direct or indirect ways you can help sustain healthy coastal habitats and encourage others to make decisions that account for these habitats and the biodiversity and livelihoods that depend on them.

Opting for sustainable consumer choices. Whether deciding where to vacation or which type of seafood product to purchase, market demand can influence investments that have negative or positive outcomes for coastal habitats and associated biodiversity where we invest our money influences how governments and the private sector prioritise spending. Educating yourself on the policies and practices of the companies you support, as well as the brands you buy, can result in daily contributions to positive changes for our planet.

Encouraging greater protection. Global momentum towards conserving the natural environment can be driven through a combination of actions. These include government commitments and efforts to document and conserve important areas, public pressure and campaigns and a mechanism to track these commitments and successes. The Convention on Biological Diversity's Aichi Biodiversity Target 11 on protected and conserved areas demonstrates how this could be done. Effective management is crucial to ensure that critical coastal ecosystems are protected from the potential threat of development or pollution. Your voice can encourage progress towards protecting vital habitats in your local neighbourhood, state or country.

Reducing carbon emissions. Climate change is affecting ecosystems globally, and coastal ecosystems are no exception. A reduction in emissions in line with the targets of the Paris Agreement can not only ease pressures on coastal habitats but also have the further benefit of ensuring that many of these healthy ecosystems can contribute to further carbon sequestration and protect coastal communities from extreme weather events.

Registering your vote. Voting for political candidates who support policies and programmes towards the above actions can help to strengthen coordinated efforts to improve the health of coastal ecosystems and the food and economic security of communities who depend on them.

Together, these actions and others as suggested throughout this book can contribute to the effective management and conservation of coastal habitats. Further, the UN declared 2021 to 2030 the Decade of Ocean Science for Sustainable Development and the Decade on Ecosystem Restoration. These declarations can provide us with the global momentum and opportunities to invest in monitoring, conserving and restoring these habitats and the associated biodiversity and benefits they provide to communities around the world.

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Lauren V. Weatherdon Like many growing up in coastal British Columbia, I have always shared a passion for the coastal flora and fauna that characterise daily living and outdoor adventures. In later years, I completed a B.A. in Honours English Literature, one year towards a B.A. in Geography, and an M.Sc. in Resource Management and Environmental Studies from the University of British Columbia. This interdisciplinary background has allowed me to experience nature in different ways, from literary explorations of how Spenser and Milton perceived nature in the 1500s and 1600s, to understanding how effective management of the ocean can improve ecological, social and cultural outcomes for society. These experiences have highlighted to me just how central nature is to individual and collective well-being for communities around the world and the importance of conserving nature not only for its intrinsic value, but also for our survival. Since 2014, I have had the opportunity to work with UN agencies, governments, companies and non-governmental partners in more than 20 countries around the world, with the shared aim to sustainably manage and conserve nature for people and planet.

Part V
How We Manage the World's Oceans

Chapter 20
Ocean Governance

Mariamalia Rodríguez Chaves and Kristina M. Gjerde

Introduction

The ocean is the blue heart of our planet, providing many indispensable goods and services in addition to boundless inspiration. Consequently, humanity depends on the well-being of the ocean.

Through many years, the international community has developed rules, mechanisms, and institutional frameworks to conserve, manage, monitor, and govern marine areas. However, most of these governing instruments were developed for national or regional areas. The following chapter aims to highlight some of these tools and regulations, embedded in international instruments and institutions that build up the architecture for our ocean's governance. One of the key challenges we will see is how to advance toward integrated, ecosystem-based management at the national, regional, and global scales in an interconnected ocean and interdependent planet. The need for ecosystem-based management is vital if we are to conserve the abundance and diversity of marine life and habitats in light of the far-ranging effects of human activities and climate change.

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UNCLOS: The Constitution of the Ocean

70% of Earth's surface is ocean: wherever you are, whatever you're doing, you are strongly connected to it.

The 1982 **United Nations Convention on the Law of the Sea (UNCLOS)** is considered the Constitution of the ocean. The Convention was negotiated over almost 10 years and is now the principal multilateral instrument regulating ocean-related activities based on a delicate balance of rights and responsibilities.

For example, UNCLOS established different maritime zones, where States have diverse degrees of rights and duties to enjoy the richness of ocean biodiversity and other resources of relevance for their economies, as well as commitments to protect the marine environment. These zones within national boundaries include internal waters, the territorial sea, exclusive economic zones (EEZ), and the extended continental shelf. Beyond national boundaries are the High Seas and international seabed area (Fig. 20.1).

The Convention is supplemented by two implementing agreements, which have been adopted to regulate in a more detailed manner two specific activities. The first activity is fishing for straddling (those fish that move between national waters and the High Seas) and highly migratory fish stocks, known as the **1995 Agreement for the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks**. The second activity is mineral extraction from the international seabed area (referred to as 'the Area'), known as the **1994 Agreement relating to the**

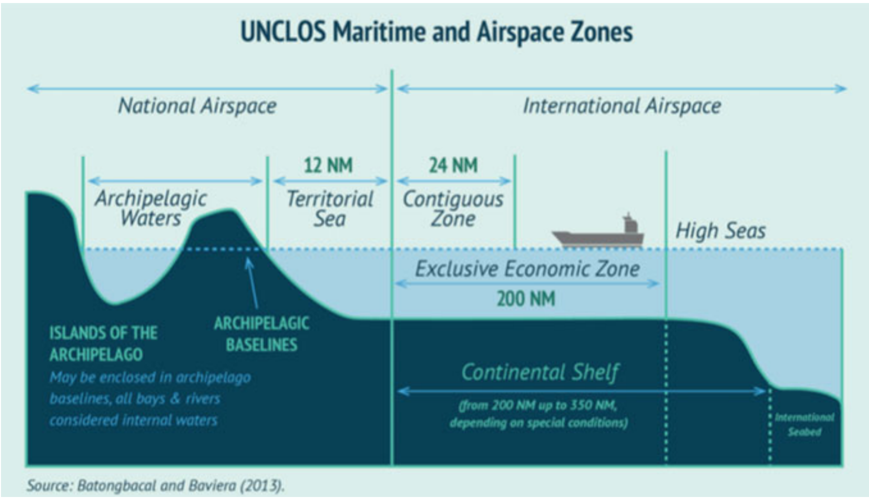

Fig. 20.1 Maritime and airspace zones established by UNCLOS

implementation of Part XI of UNCLOS. The Convention also establishes three institutions. One is the *International Seabed Authority* (ISA) to regulate and control all mineral-related activities in the international seabed area on behalf of humankind as a whole. Another is the *Commission on the Limits of the Continental Shelf (CLCS)* with a mandate to make recommendations to coastal States on matters related to the establishment of the limits of their extended continental shelf. The third is the *International Tribunal for the Law of the Sea (ITLOS),* an independent judicial body for the settlement of disputes arising from the interpretation and application of the Convention.

Relevant to bear in mind is that UNCLOS sets as primary principles the peaceful use of the ocean, the equitable use of resources, and the conservation of living marine resources, as well as the protection and preservation of the marine environment. Those of us working in the conservation field often say that far more attention has been focused on the rights to exploit and not enough on the duties to conserve, protect, and preserve. While States are able to adopt their own laws guided by UNCLOS in areas within national jurisdiction, the legal regime to protect and preserve ocean life of the High Seas and international seabed area is more complex as international cooperation is essential. Yet, the urgency for action is accelerating.

United Nations building, New York. *Credit* Tracy Williams/Greenpeace

Safeguarding Our Blue Biodiversity

It is our responsibility to adequately protect the ocean's immense and unique biodiversity.

The Law of the Sea framework is complemented by other legal instruments addressing biodiversity such as: the 1992 **Convention on Biological Diversity** (CBD), the 1979 **Convention on Migratory Species** (CMS), the 1946 **International Convention for the Regulation of Whaling** (IWC), the 1973 **Convention on International Trade in Endangered Species of Wild Flora and Fauna** (CITES), the 1972 **World Heritage Convention** (WHC), among others. Each of these biodiversity-related Conventions has governance structures, mainly comprising a decision-making body, a scientific body and a Secretariat, and other subsidiary bodies in some cases.

These instruments have developed different tools and provisions to protect and manage biodiversity. For example, marine protected areas and environmental impact assessments are key pillars for the conservation of biodiversity and ecosystems and have legal support in the **CBD** and in national legislation worldwide. The CBD has other environmental cornerstones, such as the precautionary principle; conservation tools and measures; capacity building and financial mechanisms; access to and benefit sharing of genetic resources, among many others. In 2008, scientific criteria for identifying areas that would benefit from enhanced conservation and management were created under the CBD framework: the *ecologically or biologically significant marine area* (EBSA). These criteria include uniqueness or rarity; importance for threatened, endangered or declining species and/or habitats; vulnerability, fragility, or slow recovery; among others, with the goal of promoting the adoption of appropriate measures for their conservation and sustainable use such as area-based management tools within and beyond national jurisdiction.

Rules governing the trade of vulnerable and endangered species are framed in **CITES**, which sets forth requirements to control the import and export of species and related products of wild fauna and flora, including marine species. It also sets different obligations for States on the basis of an Appendix approach, where the level of protection for the species depends upon their specific listing in such Appendices. For example, the endangered whale shark is listed in Appendix I, and therefore, its international commerce is prohibited. Other regulations apply to hammerhead sharks, which are included in Appendix II, and its international export or import is subject to specific requirements such as an export certificate.

Our interconnected ocean is also the playground of highly migratory species, such as whales, fish, sharks, seabirds, turtles, among many others, and **CMS** provides important mechanisms for their protection. Similar to CITES, CMS addresses management and conservation measures through Appendices. For example, it requires immediate protection for migratory species included in Appendix I (such as the Blue Whale and the Oceanic White Tip shark), and encourages the establishment of Agreements to advance cooperation on conservation and management of migratory species included in Appendix II. CMS emphasizes the critical role of transboundary conservation measures, including, for example, ecological networks of protected areas to improve the connectivity among areas within and beyond national jurisdiction.

Whales, highly migratory and charismatic species, have found legal protection also through the **IWC**, an instrument adopted in 1946 initially to regulate whaling and only later to protect them. In 1982, after years of campaigning by conservation groups, the IWC finally adopted a complete ban on commercial whaling. Still, whaling activities under the scientific whaling exemption have been undertaken by a handful of countries.

The **WHC** sets forth the criteria for the protection of areas of natural and cultural heritage both on land and at sea. The World Heritage List under this Convention includes habitats of outstanding universal value for conservation purposes. Once a site is designated and included into this list, all countries have the obligation to ensure its protection. Examples of such sites include Australia's Great Barrier Reef, the Galapagos Islands, and New Zealand's Sub-Antarctic Islands.

Despite this regulatory architecture, the loss of biodiversity continues.

To date, most governing and conservation tools have focused on national and regional waters. In contrast, little attention has been given to the High Seas, the two-thirds of the ocean beyond the maritime boundaries of States. Biodiversity in this vast area of the ocean is also threatened and subject to increasing pressures. For the past 15 years, States at the United Nations have been discussing—and since 2018 formally negotiating—a new **Treaty for the conservation and sustainable use of biodiversity in areas beyond national jurisdiction** (BBNJ Treaty). When UNCLOS was negotiated in the 1970s, humanity did not have the knowledge, and foresight that we have nowadays concerning this vast ocean realm. The Convention therefore fails to address the emerging challenges faced by biodiversity due to expanding human uses and climate-related changes.

Therefore, the backbone of this new Treaty encompasses four key elements: (1) access to marine genetic resources and benefit sharing; (2) area-based management tools, including marine protected areas; (3) environmental impact assessments, and (4) capacity building and transfer of marine technology. The BBNJ Treaty is on its finish line to be agreed. Many hope to conclude the treaty in early 2023, ideally with robust and ambitious provisions to protect the marine environment and its diversity in the High Seas and seabed area. Once finalized, this treaty will be considered the third Implementing Agreement supplementing UNCLOS.

How Do We Manage Fisheries Within and Beyond State Waters?

Fish are a core component of biodiversity.

Fisheries are largely managed following a species-specific approach although the goal has long been to apply a comprehensive ecosystem-based management approach. Governance arrangements and management measures have been developed through international conventions and subsequent provisions from the UN Food and Agriculture Organization (FAO) and Regional Fisheries Management Organizations (RFMOs). Yet, as discussed in Chap. 6, marine fishery resources worldwide have been in a continuous decline with at least one third of fish stocks fished at unsustainable levels. This overfishing and under-regulated fishing has serious implications for the health of the targeted fish stocks as well as other species and can undermine the integrity and resilience of marine ecosystems as well as food security for coastal nations.

The 1995 **Agreement for the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks** (Fish Stocks Agreement) supplements the fisheries provisions in UNCLOS by elaborating the duty of States to cooperate to ensure the long-term conservation and sustainable use of straddling and highly migratory fish stocks. This agreement operationalizes the precautionary approach and supports the compatibility of management and conservation measures both within and beyond national jurisdiction. Likewise, the Fish Stocks Agreement sets out obligations for States to cooperate either directly or through RFMOs by elaborating the specific functions of RFMOs and limiting access to fishery resources to those States who agree to join the RFMO or abide by its rules. This means in theory that fisheries management arrangements are generally agreed by a group of States on a regional basis but in practice are guided by States with an economic interest in the fishery.

In the 1993 **FAO Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas** (FAO Compliance Agreement) flag States are the principal actors, and they must ensure that vessels flying their flag 1) do not engage in activities that undermine international conservation and management measures, and 2) provide information on operations, catches, and landings. In combatting unauthorized activities, cooperation and exchange of information are key tools included in this agreement.

Illegal, unreported, and unregulated (IUU) fishing is one of primary threats to biodiversity, having a major bearing on the health of marine ecosystems and species. The 2016 **FAO Agreement on Port State Measures to Prevent, Deter, and Eliminate IUU Fishing** (FAO Port State Measures Agreement) sets out key requirements and processes regarding the entry, use, and denial of ports. Consequently, Port States must request specific information from a fishing vessel before granting entry to port and proceed with follow-up actions if it is established that a vessel is engaged in IUU fishing or prohibited fishing. See Chap. 7 for more on fish crimes.

In relation to deep-sea fisheries caught with heavy bottom trawls and other bottom contact gear, the 2008 **International guidelines for the management of deep-sea fisheries in the high seas** provide non-binding rules to guide RFMOs and States in regulating these high seas fish stocks. These fisheries are particularly challenging as many deep-sea fish mature late and have extremely low productivity and dwell in or close to rare and fragile deep seabed habitats like corals. The guidelines, agreed to by the United Nations General Assembly, seek to prevent significant adverse impacts on vulnerable marine ecosystems (VMEs), defined as those that are unique or rare, fragile or structurally complex. Once a VME has been identified, specific management measures are to be taken to ensure that the ecosystem's integrity is not compromised, such as fishing closures, changes in gear design, monitoring of fishing efforts, among others, or the fishery is not to be approved.

Finally, other instruments such as the 1995 **FAO Code of Conduct for Responsible Fisheries** and the legal framework governing activities of RFMOs could also inform countries' legislations on fishing activities.

Sperm whales. *Credit* Amanda Cotton

All on Board! Navigating the Wide Ocean

Over 80% of world trade by volume is carried by sea. Thus, our ocean is getting busier and busier with vessels, its associated pollution, ocean noise and potential collisions with marine mammals.

The **International Maritime Organization** (IMO) was established in 1948 as an Intergovernmental Organization to regulate international shipping and navigation for safety, vessel source pollution, and maritime security. IMO's challenge is to balance the rights, duties, and interests of coastal States with the rights and interests of flag states who enjoy the freedom of navigation subject to the universal duty to protect the marine environment.

One of the most important pollution instruments is the 1973 **Convention for the Prevention of Pollution from Ships as revised in 1978** (MARPOL 1973/1978), which promotes the prevention of pollution by ships from both operational and accidental causes. These provisions are further developed in six technical Annexes, addressing different types of pollution. Some of these Annexes include rules for the designation of *special areas*, where the adoption of special methods to prevent pollution is required (for example, the prohibition of oily tank washings, disposal of plastics, toxic, or heavy metal residues).

Additionally, the 1972 **Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter,** (the **London Convention**), aims to control and prevent marine pollution by prohibiting the dumping at sea of land-based waste likely to create hazards to human health or harm marine ecosystems and biodiversity. Through the years, amendments to this Convention gradually broadened into dumping prohibitions, and in 1996, the London Protocol prohibited all dumping, with some listed exceptions. Moreover, the protocol has sought to respond to new and emerging threats to the marine environment, such as ocean geo-engineering and more specifically iron fertilization of the ocean, which are touted a means to reduce atmospheric carbon dioxide levels through a new Annex 4 of the London Protocol, but is not yet in force.

Another important instrument is the 1969 **International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties**, facilitating regulations to mitigate or eliminate grave and imminent danger from pollution by oil, following a maritime casualty. A 1973 Protocol to the Intervention Convention relates to spills of other hazardous substances.

Finally, in relation to area-based management tools (ABMTs) that could be established under the IMO's auspices are the **Particularly Sensitive Sea Area (PSSA),** a concept elaborated in the 2006 guidelines for the identification and designation of PSSAs. This sectoral ABMT can be applied to protect an area that meets recognized ecological, socioeconomic, or scientific criteria, with the subsequent adoption of protective measures from international shipping. Important to highlight is that to date, no PSSA has been designated for High Seas areas.

Mining the Last Frontier?

In the deep-ocean floor cold-water corals, sponge fields, seamounts, hydrothermal vents and other ecosystems are home to mysterious creatures found nowhere else on Earth.

The deep seabed is home to a wide variety of biodiverse—and yet to be discovered – ecosystems as well as minerals of increasing commercial interest. The deep seabed area (beyond national boundaries) is deemed by UNCLOS to be the "common heritage of humankind." The International Seabed Authority (ISA) was established to regulate and control all mineral-related activities for the benefit of humankind as a whole. The legal framework on seabed mining includes Part XI of UNCLOS, the 1994 Agreement relating to the implementation of Part XI—and more recently—regulations on prospecting and exploration for polymetallic nodules, cobalt-rich crusts, and polymetallic sulfides. Regulations that would govern mineral exploitation in the area are currently under development. National laws and regulations are to be "no less effective than" these developing international rules.

There is widespread concern about deep seabed mining and its impacts on the ecosystems and species of the deep ocean, as the possibility of significant adverse impacts could entail damage to the seafloor, sediment plumes, noise and vibration, among others. Therefore, is it more critical than ever to recall and enforce UNCLOS' key obligation to protect and preserve the marine environment and to exploit natural resources in accordance with sound environmental policies.

One type of area-based management tool has been created in this sectoral regime, areas of particular environmental interest (APEIs), in which closures to mining are established to protect regional biodiversity and representativity of ecosystem structures and functions. A network of APEIs is the main component of the Regional Environmental Management Plan for the Clarion-Clipperton Zone in the Pacific Ocean. However, APEIs will need to also be accompanied by stringent environmental regulations based on solid science to prevent harmful impacts to marine life, water quality, and food safety in the wider environment.

Discovering Our Ocean's Wonders: Marine Scientific Research

We will conserve only what we love, we will love only what we understand.

Marine scientific research (MSR) is governed by Part XIII of UNCLOS based on key principles that it must be conducted for peaceful purposes, with appropriate scientific methods, and complying with marine environmental regulations.

Following UNCLOS's zonal approach, Part XIII regulates MSR in accordance with the different maritime zones. Consequently, different rules apply depending on whether the scientific activities are to take place within the territorial sea, the EEZ, or extended continental shelf. In the High Seas and the Area, MSR is recognized as one of the key High Seas freedoms.

In addition, access to relevant marine technology is vital for many developing countries to conduct MSR, and Part XV of UNCLOS reinforces the importance of cooperation for the development and transfer of marine technology. In this context, the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific, and Cultural Organization (IOC-UNESCO) is responsible for marine science in the United Nations system. This Commission has advanced a framework to help operationalize UNCLOS provisions on MSR, capacity building, and the transfer of marine technology through instruments such as the 2003 Criteria and Guidelines for the Transfer of Marine Technology.

However, there is much more that could be done to advance the capacity of developing countries to engage in MSR to understand, manage, and conserve ocean life and sustainably use marine genetic resources including in ABNJ. It is hoped that the new BBNJ Treaty can accelerate progress on multiple fronts.

In Summary

During the past decades, humankind has established governance structures—encompassing legal instruments and institutional frameworks—applicable to activities benefiting from marine resources and biodiversity within and beyond national boundaries such as navigation, fisheries, seabed mining, and marine scientific research, among others.

Other multilateral frameworks in place seek to ensure the conservation, sustainability, and resilience of our ocean and its fragile and rich ecosystems and biodiversity. However, to date, these conservation-related agreements have focused largely on ocean areas within national jurisdiction. Hence, the emerging treaty for Biodiversity Beyond National Jurisdiction (BBNJ) will be an important tool for safeguarding ocean species, habitats, and ecosystems spending all or even part of their time in Areas Beyond National Jurisdiction (ABNJ).

Today, we know that our ocean and its biodiversity are not limitless, and the more we understand the marine environment and its inhabitants, the greater our responsibility is to protect it for our own survival.

Meeting room at the United Nations, New York. *Credit* Mariamalia Rodríguez Chaves

Ways to Get Involved

The development of national and multilateral legal frameworks and policies that govern and protect the ocean is in the hands of national governments representatives, such as law- and policy-makers. However, the agreements that are finally reached are often influenced by interest groups. In addition to industry, environmental campaigning organizations, conservationists, scientists, and other concerned groups can actively participate as observers in multilateral negotiations. These same groups can often campaign in-country and encourage national governments to make stronger commitments to ocean protection. Similarly, representatives from industry groups will be lobbying their interests for access to marine resources or perhaps fewer pollution controls.

As a citizen, there are a number of ways you can have your voice heard. You can support and join those groups that are engaged in matters of ocean policy, either at the national, regional, or global level. You can also organize within your own community to let your government know that the ocean is important to you. Finally, and perhaps most powerfully, if you have the privilege to exercise your vote in election cycles, then use it and seek out those representatives that have the health of the ocean high on their agendas.

Some organizations currently actively working on international policy setting for the ocean include:

- High Seas Alliance (marine biodiversity beyond national jurisdiction Treaty) http://www.highseasalliance.org
- Deep Sea Conservation Coalition (deep-sea bottom fishing and deep seabed mining) http://www.savethehighseas.org
- Deep Ocean Stewardship Initiative (deep ocean science to policy volunteer network) https://www.dosi-project.org/.

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Dr. Mariamalia Rodríguez Chaves I am a Costa Rican environmental lawyer and I have worked in Non-Governmental Organizations on a variety of topics, including renewable energy, marine conservation, and management schemes, and most recently, I completely fell in love with the High Seas, its biodiversity, and governance regimes. My Ph.D. research—at the National University of Ireland—focused on high seas governance in a very special ocean area called the Costa Rica Dome. This part of my academic life greatly complemented my work in the High Seas Alliance, as I follow closely the negotiations of a new Treaty for the conservation and sustainable use of marine biodiversity in areas beyond national jurisdiction.

I am also part of a Gender Empowerment Program for the United Nations Decade of Ocean Science at the WMU-Sasakawa Global Ocean Institute, where my post-doctoral research explores gender equality and the role of women in governance bodies that mediate the delivery of ocean science into policy action. From both spheres of my work, I can see that real-transformative change is urgently needed, and that is why we need more people involved, engaged, and aware to ensure this happens.

Kristina M. Gjerde I am currently Senior High Seas Policy Advisor for the International Union for Conservation for Nature (IUCN) as well as an adjunct professor at the Middlebury Institute of International Studies, where I teach international ocean law. I trained as a traditional lawyer but was always drawn to international law, the ocean and the power of international collaboration. From early on, I saw international law as a tool to advance ocean conservation and improve ocean management. At first, I assumed it would be enough to work through existing institutions such as many of those described in this chapter. But, after spending time seeking to advance conservation issues related to shipping and fishing at the International Maritime Organization and the UN Food and Agriculture Organization, I realized that these disparate efforts were not enough to secure comprehensive protection for priority areas in the High Seas and deep seas, or to secure ecosystem-based and ecologically-sustainable management. Many others have shared this journey with me and are eager to move beyond the status quo; to create a robust global agreement enabling the establishment of systems of Marine Protected Areas in Areas Beyond National Jurisdiction, as well as mainstream biodiversity protection and ecosystem-based management into the mandates and actions of all. I hope you will join us in this effort! (see the full interview here: https://www.dosi-project.org/interview-kristina-gjerde/).

Chapter 21
Marine Protected Areas

Jean M. Harris and Amanda T. Lombard

What are Marine Protected Areas?

Marine protected areas (MPAs) are areas in the ocean (including estuaries) that restrict human activity primarily for biodiversity conservation purposes, whilst delivering social, cultural and economic benefits. MPAs can be fully protected (with no extractive or destructive activities allowed), highly protected (with only light extractive activities allowed), lightly protected (moderate to significant extraction and impacts allowed) or minimally protected (extensive extraction and other impacts allowed). Other effective area-based conservation measures (OECMs), such as indigenous and community-managed reserves, or areas of historical significance, as well as vulnerable marine ecosystems (VMEs) and ecologically or biologically significant marine areas (EBSAs) may also provide some conservation benefit even though they are not MPAs. Additional demarcated areas in the ocean such as fishery management zones or military areas do not have biodiversity conservation objectives but can be integrated into broader conservation efforts that build social-ecological resilience.

Different legal frameworks for MPAs exist. Within countries' national waters (also called exclusive economic zones—EEZs), many countries have established MPAs close inshore, but there is a recent effort to establish MPAs in deeper offshore areas. Outside of exclusive economic zones, in the area called areas beyond national jurisdiction (ABNJ), the "High Seas" and "The Area" (which refers to the seafloor), MPA establishment requires international agreements.

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MPAs are important tools in an integrated ocean management toolbox required to address the multi-faceted and complex challenges facing our oceans and to build long-term social, ecological and economic resilience. MPAs are central to an ecosystem-based approach to marine spatial planning (MSP), which aims to address conflicts between users of the ocean space and to allocate access to marine resources sustainably and efficiently through space and time. Significantly, the need to undertake equitable, stakeholder-driven MSP processes has been identified as key to developing a sustainable future for the oceans, within new drives for "Blue Economies" in keeping with the principles of promoting economic growth whilst ensuring environmental sustainability.

Bay iSimangaliso MPA. *Credit* Bryan Hart

Why Do We Need MPAs?

The health of the oceans, and the benefits (ecosystem services) they provide humankind, is currently at unprecedented risk. We are experiencing two interlinked major ocean crises, namely biodiversity loss and climate change effects, which are severely compromising the delivery of the ecosystem services we depend on (such as climate regulation, oxygen production, food security, economic assets underpinning tourism and recreation). These ecosystem services sustain humanity, and healthy oceans provide resilience to unknown events in our future. These two major ocean crises are human induced, caused by overfishing, illegal fishing, habitat destruction, pollution and ocean warming and acidification. Scientists have predicted that unless this negative trend is arrested over the next decades there will no longer be viable fish stocks to sustain fisheries, more than 90% of the world's coral reefs will die, areas of the ocean will become "dead zones," and we will face extinctions of many marine species.

Marine protected areas are a crucial tool to avert this unthinkable disaster; to prevent, halt and reverse the degradation, we are currently witnessing. Importantly, MPAs can address multiple threats and risks simultaneously, reviving fisheries whilst at the same time protecting and restoring biodiversity, thus building resilience for both the marine biodiversity they protect as well as the people who depend on the ecosystem services they provide. The benefits and functions of MPAs are multiple and diverse:

- Protect representative samples of marine biodiversity, at ecosystem, species and genetic levels.
- Restore damaged/threatened ecosystems and support the recovery of endangered species. MPAs are especially important for protecting the nursery and breeding areas of endangered species.
- Protect sensitive habitats and ecosystems from harmful human activities and species from fishery bycatch problems.
- Improve fisheries and food security (providing nursery and breeding areas for fish, allow fish stock recovery and spill-over into adjacent unprotected areas, and preserve the genetic health of fished species).
- Represent economic assets in the seascape (acting as magnets for nature-based tourism and enhancing fishery yields).
- Improve livelihoods through food security and job creation.
- Provide economic opportunities through nature-based tourism.
- Enable recreational, sport and educational activities.
- Protect natural, cultural and spiritual heritage.
- Provide resilience to negative impacts of climate change (ecosystems inside MPAs recover more quickly from disaster events like storms and coral bleaching).
- Help to slow down (mitigate) climate change (by protecting ecosystems such as corals and mangroves that are carbon sinks, where carbon is stored or sequestered).
- Reduce risks from (adapt to) climate change impacts, such as storms and flooding (climate adaptation) by providing physical protection from storm surges (healthy fringing reefs) and floods (healthy mangroves in floodplains and coastal areas).
- Offer good economic investment providing "insurance" against uncertainty and disasters.

MPAs are also the only means by which we can protect biodiversity from some human activities that destroy marine habitats, such as seabed mining and bottom-trawling. In fact, MPAs are one of the best nature-based solutions to the problems faced by the oceans. Although MPAs cannot stop ocean warming, acidification or pollution, by having healthy habitats and species, they can regenerate by bouncing back quickly from shocks, and they can continue to deliver the ecosystem services we need from the ocean. Many studies have measured the success of MPAs in meeting the multiple aspirations (objectives) we have identified for them, and the results are very encouraging.

Potato Bass—Sodwana Bay MPA. *Credit* Bryan Hart

How Much of the Ocean Should Be Within MPAs?

This question has been the subject of much debate amongst both scientists and policymakers over the last few decades. Most people agree that at least some of the ocean needs to be left alone in a natural state, but the big question is how much ocean protection is enough to gain the benefits described above, at both local and global scales. In 2002, at the United Nations World Summit on Sustainable Development, nations agreed to establish national networks of MPAs, but quantitative targets or levels of protection were not decided. This step advanced into a target of 10% of the oceans to be included in MPAs by 2020 (10 × 20), included as Target 11 of the Convention on Biological Diversity "Aichi Targets" at the Conference of the Parties (COP) of the United Nations (UN) in Japan in 2010. This target was reinforced by the United Nations Sustainable Development Goal (SDG)14 (Life below Water). Although a big step in the right direction, this target seeks to bring unity and action at a global and national level and is a compromise negotiated on a political stage. Recent scientific evidence suggests that a much bigger target of 30–50% of the ocean may require protection if we hope to ensure persistence and viability of all marine habitats and species and to maintain healthy oceans. The International Union for the Conservation of Nature (IUCN) members at the World Conservation Congress held in Hawai'i in 2018 supported a new global target of "30% of each marine habitat" to be set aside in "highly protected MPAs and other effective area-based conservation measures" by 2030. Other conservationists have advocated that 50% ("Half Earth" concept) is required to sustain the health of the planet especially when considering the increasing uncertainty and impacts from climate change.

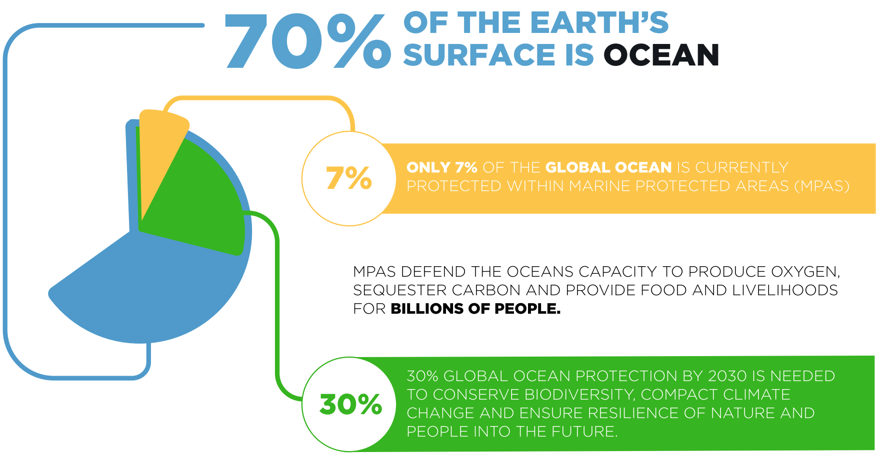
Embodied in these Aichi and SDG targets is the need to ensure that ocean protection is achieved within highly protected areas (preferably no extraction or disturbance) that are effectively managed. Some voices have criticised recent MPA expansion efforts, suggesting that governments should only designate MPAs when they have the resources to manage them, but it is generally accepted that there is an urgent need to protect more of the ocean within MPAs, whilst at the same time working to improve the effectiveness of how they are managed. In addition, MPA establishment must be undertaken in a fair, just and transparent way (which has not always been the case in history) so that people value them and receive the benefits from them. It is encouraging that many community-based MPAs are emerging, especially in developing countries where government capacity is weak. Another key consideration is devising mechanisms for sustainable financing of ongoing MPA management. There are advances in this regard through partnerships with the private sector and financial institutions. Currently, approximately, 7% of the ocean falls in MPAs, of which only around 3% is highly protected in designated no-take areas.

MPAs and the Blue Economy

Globally, there is a move to promote a "Blue Economy," recognising the essential services the ocean provides to humankind go far beyond food and jobs (and every second breath we take), and pertain to the whole planet and its people wherever they live (not just in coastal communities). Direct economic benefits derived from the ocean include not only industries such as fisheries, mining, transport, and tourism, but intact marine and coastal systems can save billions by protecting coastal infrastructure and communities from floods and storm damage. To track and value these services, ocean accounting exercises are being pursued with support from the World Bank and other significant donors.

The promotion of Blue Economies, currently at the heart of many national development plans around the world, is narrowly focussed on a notion that there are untapped resources and opportunities to be had from the ocean that will replace the over-exploited resources provided by depleted terrestrial systems (such as forests and mines). The Blue Economy drive aims to foster investment and create jobs and focuses on stimulating and rejuvenating the mining and energy sectors, aquaculture, shipping and tourism industries (see Chap. 22 for more on the Blue Economy). However, ocean health is at risk owing to escalating anthropogenic threats, and ocean space is becoming crowded, creating conflict between activities. Marine spatial planning, with MPAs nested within these plans with at least 30% allocated to ocean protection, has the potential to prevent activities overstepping environmentally supportable thresholds and undermining the ability of the ocean to keep the planet habitable.

The economic value of ocean protection within MPAs has recently been the subject of a number of studies. For example, the global financial benefits provided by healthy coral reefs, mangroves and coastal wetlands for coastal protection, fisheries, tourism, recreation and carbon storage have been estimated at around $600 billion for achievement of just 10% of the ocean space within MPAs by 2050, with a whopping $900 billion for protecting 30% of the oceans by 2050. MPAs thus make economic sense and are a wise investment in the future. Recently, over 100 top economists and scientists estimated the economic value of ocean protection, looking at: the insurance value of marine protection (reducing risks); recreational value (a shark or whale is more valuable alive than dead); economics of fisheries benefits; carbon capture value of productive oceans; option values for future generations; climate resilience value of protection and equity values. They concluded that 30×30 is affordable, and that to achieve this only 0.16% of global GDP (approximately $140 billion) is needed, and this would generate an investment return of at least 5:1. In short, they concluded that 30 × 30 MPA coverage would provide an affordable, cost-effective mechanism to boost the global economy!



Graphic: Protection for the Oceans

In Summary

Ocean health is at risk owing to escalating anthropogenic threats, and ocean space is becoming crowded, creating conflict between activities. Marine spatial planning

(MSP) aims to mediate between economy drivers to prevent activities overstepping environmentally supportable thresholds and undermining the ability of the ocean to keep the planet habitable. Within MSP frameworks, MPAs are essential if we hope to manage uncertainty, promote ocean health and support resilient economies. They are a critical means of reducing ocean risk from anthropogenic impacts, providing long-term insurance against short-term threats. They provide refuges for threatened species, allow damaged ecosystems to recover and help rebuild collapsed fish stocks. They offer direct economic and social benefits to people, as well as climate mitigation services for the entire planet.

Actions to Take

- Reduce your carbon footprint and inform yourself about how MPAs help to sequester carbon, slowing down the effects of climate change, as well as mitigating climate change impacts.
- Make sustainable seafood choices and inform yourself about how MPAs help to restore and sustain fisheries.
- Support organisations working to protect the ocean, especially those working for MPA expansion and effective management.
- Travel the ocean responsibly and practise sustainable tourism—leave nothing behind but footprints, take nothing but photos when you visit MPAs, and support communities living next to MPAs by buying local crafts and using local accommodation and restaurants.
- Contact your government representatives and law makers for action in existing MPAs and for expansion of MPAs to include other important areas and for your country's commitment to a global 30 × 30 target.
- If you live near an MPA, start a volunteer group to help the authorities to manage it (for example, by collecting litter from beaches, removing fishing line from rocks and reporting illegal activity).

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The MPA Atlas https://mpatlas.org/

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OceaniMPAct Campaign Ocean Impact | About MPAs

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Chapter 22
Ensuring a Sustainable and Equitable Blue Economy

Sarah Harper and Colette Wabnitz

Introduction

Humans have long relied on the ocean for food, trade, transportation, and recreation. For many communities around the world, the ocean is also central to their cultural and traditional practices. While the ocean has long been responsible for supporting human wellbeing, there is renewed interest from governments and investors in the economic development potential of ocean-related industries—existing and emerging. As the human population has increased exponentially over the past centuries, we have exhausted the riches of land-based resources and spaces much faster than those in the ocean, or at least for certain industries. In response, many countries, operating under the dominant capitalist economic system that relies on continuous growth, have turned optimistically to the ocean to further the goals of sustainable development, improved livelihood opportunities, and income generation. In much the same way as the industrial revolution promised to improve human welfare in the 1700s, today, the 'Blue Economy' offers similar promises, engaging technology, and innovation to tap into the ocean's economic development potential while supporting environmental stewardship and protection. Small Island Developing States (SIDS) have been at the

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forefront of promoting this concept, which is now widely embraced to capture a range of objectives related to ocean governance recognition of cultural ties to the ocean derived from tradition and customary marine tenure. However, what a ‘Blue Economy’ represents, what it includes and how it is understood varies greatly across different sets of actors and geographies. Notably, the recent discourse around the Blue Economy and the many ways in which it is being implemented, lack much of its original emphasis on socially equitable and sustainable development. In this chapter, the concept of the Blue Economy is outlined, with a description of some of the emerging challenges and considerations for realizing a sustainable and equitable ocean economy.

Wind farm in the North Sea. *Credit* Luca Marino/Greenpeace

What is the Blue Economy?

The concept of the Blue Economy formally emerged in the lead up to and during the United Nations Conference on Sustainable Development in 2012 (also known as the Rio + 20 conference). The Blue Economy was framed as a means to achieve improved human wellbeing and social equity, while significantly reducing environmental risks and ecological scarcities, endorsing low carbon, resource efficiency, and social inclusion. The concept quickly gained steam following Rio + 20 with many, including the World Bank, developing similar definitions that emphasized economic development that promotes improved human wellbeing and social equity, while at the same time decreasing environmental risks and consequences. In essence, the concept emerged from a need and a desire to integrate conservation and sustainability goals into marine-related economic development, inclusive of social, economic, and ecological dimensions. What distinguishes the 'Blue Economy' from the 'Ocean (or Marine) Economy', broadly, is the emphasis at its core on social equity alongside sustainability considerations. While the ocean economy comprises any and all economic activities (public and private but excluding non-market values) related to oceans, the concept of 'Blue Growth' refers to the expansion of ocean sectors in a market economy sense with some implied observance to environmental sustainability. However, increasingly the terms Blue Economy, Ocean Economy and Blue Growth are used interchangeably, which they should not, as this causes confusion and adds to the challenges associated with realizing the Blue Economy.

Ocean-related sectors such as fisheries are some of the oldest industries in the world, so the Blue Economy is not simply about continuing business as usual, rather it is about changing how we view exploitation of the ocean. A key principle is that any economic benefits derived from the ocean must pay careful attention to the ecological systems supporting these activities and the communities that depend on it. Investments in the Blue Economy should therefore always be linked to ocean health and with a view to improve human wellbeing and social equity. While ocean-based sectors include both traditional industries (e.g., fisheries, transport, fossil fuels, tourism) and emerging industries (e.g., aquaculture, renewable energy, biotechnology, deep seabed mining, tech-related services), there are differing opinions on what should be considered as part of the Blue Economy. Some think that the Blue Economy should include only those ocean industries that meet the criteria of being socially and ecologically sustainable. This means that carbon-intensive oil and gas industries, for example, or deep-sea mining, where there are increasing concerns about irreversible harm to deep-sea habitats, would not be included. Aquaculture, fisheries, marine renewable energy, high technology marine services, and marine biotechnology on the other hand, if done sustainably, could contribute to the growth of the Blue Economy. Central to the debate over what sectors to include is whether the Blue Economy should be positioned as an aspirational process to move toward more sustainable and equitable sectors or whether it should be a defined approach with clear boundaries.

Kelp harvest. *Credit* Cascadia seaweed corp

Given that the Blue Economy is in development, finance is necessary to leverage and benefit from new and expanding industries and opportunities. This financing can be in the form of: (a) grants, where finance is provided without the expectation of repayment; (b) loans, where finance is provided on the condition of repayment and usually interest; or (c) other debt instruments, such as bonds, where money is invested on the premise that on the date of maturity, the principal investment and interest will be paid out to the investors. The funds for these can be raised and administered by multilateral organizations such as the United Nations and the World Bank, private investors and donors, national governments, and philanthropic organizations, which then provide financing opportunities to individuals, businesses, and/or local communities through a variety of programs and other mechanisms. The World Bank, for instance, has mobilized billions in US Dollars to support Blue Economy programs such as PROBLUE, a multi-donor trust fund, housed at the World Bank, that supports the development of integrated, sustainable, and healthy marine and coastal resources. Since these types of investments have a high degree of risk and often do not provide the economic returns demanded by private investors, other models such as 'Blended Finance' are being increasingly promoted. Blended finance is described as the use of capital from public or philanthropic funds to increase private sector investments in sustainable development. Essentially, this is more attractive to private investors because public or philanthropic actors take on some of the risk. An example of this type of innovative financing is Blue Bonds, pioneered in the Republic of the

Seychelle's through their Blue Grants Fund, a blended finance mechanism to support sustainable fisheries initiatives and the conservation of marine areas. While some see the Blue Grants Fund as being very successful in advancing inclusion and increasing participation across societal groups, providing grants to community groups, such as environmental nonprofits, young entrepreneurs, women-led initiatives, and small-scale fishers, others have been more critical. One of the critiques of this fund is how, in its current form, it prioritizes economic goals at the expense of environmental and social equity outcomes. What this highlights is that innovative finance mechanisms are crucial to support planning and the realization of the Blue Economy, but approaches must be attuned to and balance social, economic and ecological objectives, and trade-offs.

What Are the Challenges?

As many countries are quickly embracing the promise of the Blue Economy, without considering fully the social, economic and environmental risks associated with its expansion, many people fear that this concept is merely a rebranding of "business as usual." For example, there are numerous examples from around the world of community displacement, habitat destruction, and loss of traditional fishing grounds by artisanal fishers as coastal states seek to harness emerging opportunities within their oceans, without considering the trade-offs. With an eye to these social equity considerations, the concept of Blue Justice within the Blue Economy has emerged, primarily in response to the negative impacts of rapidly developing ocean sectors on small-scale fishers. With millions of people around the world either directly or indirectly dependent on small-scale fisheries, rapidly developing and expanding ocean sectors that compete with fisheries for space and resources may pose a considerable threat to the food and livelihood security of millions of people globally. Intersectoral challenges and conflicts are also a threat, for example, the growing and serious concern about illegal, unreported, and unregulated (IUU) fishing activities around the world, undermining Blue Economy efforts (see Chap. 7 on Fish Crimes). For some ocean-related industries, the conversation is slowly shifting toward a sustainable Blue Economy, re-emphasizing the need for marine health, social equity, and economic development to co-exist within Blue Economy frameworks. However, there needs to be broader dialogue and critical perspectives on the social equity considerations related to the Blue Economy if it is to deliver on its original promise.

Equity considerations need to be maintained as a central feature in Blue Economy discourse and policies with the consideration, inclusion, and participation of all groups irrespective of age, gender, ethnicity, and economic background. History abounds with examples of groups that have been and continue to be marginalized in the use and protection of ocean resources with only certain segments of society benefiting and being represented in decision-making to the exclusion of others and marginalized groups bearing the consequences of such use. Unfortunately, this continues to be evident with the invisibility of women in the fishing sector (see Chap. 29 on Gender and the Ocean) and the fact that so few countries benefit from the resources found on the High Seas. For all interested countries to be able to participate in and benefit from the Blue Economy, financing schemes are required that ensure that no country is left behind. Developing countries where public funds are insufficient to meet development needs, and even those seeking foreign aid, are especially constrained in terms of ocean financing, which typically receives the least investments. The transition to a sustainable and equitable Blue Economy must include everyone and support just transitions for those who might be displaced along the way toward realizing the broader goals of sustainability and equity as was the original intent for the Blue Economy.

The Blue Economy has been positioned to promote economic resilience in developing countries, in particular for Small Island Developing States, to support the diversification of an economy primarily dependent on tourism and fisheries. However, much of the early emphasis on and excitement for the Blue Economy fails to consider the financial, technological, policy and operational capacity constraints of many coastal and Small Island Developing States. In Africa, a review of Blue Economy projects identified that insufficient knowledge, limited technological capacity, and investment have made the Blue Economy more challenging and difficult to develop. Since many coastal and Small Island Developing States lack the financial and technological capacity to develop a successful Blue Economy agenda, there is a risk of deepening social and economic inequalities among countries. However, it is important to note that in some cases, what coastal communities may need the most is sovereignty over their resources, before even considering how to further develop these. Sovereignty issues aside, to be true to the notion of the Blue Economy, and for it to be accessible broadly, financial support will need to be provided to level the playing field—to provide opportunities equitably, and especially for developing economies.

As existing approaches governing ocean industries and spaces fall short in advancing social equity and environmental sustainability objectives of the Blue Economy; new institutions and mechanisms are needed. For example, intergovernmental organizations such as the United Nations should establish or designate a commission or agency to be responsible for ensuring best practices and guidelines for the implementation, monitoring, and management of Blue Economy activities. This should involve guidance on capacity building at all scales and for developing context-specific approaches for the Blue Economy. The revamping of institutions to support the Blue Economy requires reimagining the ocean as a shared space. The ocean and its resources should be capable of providing social, environmental, and economic benefits to society broadly. This can only be realized if governance mechanisms are committed to transparency and coordination across contexts, scales, and industries to better understand and balance competing objectives and values. Transparent and inclusive processes are more likely to garner support for the concept of the Blue Economy, build trust and legitimacy in governance institutions and mechanisms, and reduce potential conflicts among actors.

Keeping Both Environmental Sustainability and Social Equity at the Heart of the Blue Economy

Realizing the potential of the Blue Economy, in providing benefits to society broadly, requires purposeful consideration of social, economic, and environmental impacts and trade-offs. Otherwise, we risk making existing problems such as socioeconomic inequalities within and between countries worse. We also risk causing further degradation of ocean spaces and resources that causes harm to both existing and future generations. As countries continue to develop and embrace Blue Economy planning, it is not too late to prioritize and re-emphasize equity and sustainability considerations. This requires that policy- and decision-makers deliberately address the red flags that are being raised as Blue Economy developments charge ahead with a 'business as usual' approach. Drawing from the work of academics, practitioners and researchers on this subject, here, are key considerations for a Blue Economy that adheres to its promise of sustainability and equity:

- Develop and support inclusive planning and governance processes to engage all relevant ocean actors and sectors, especially those such as women and minority groups whose voices are often marginalized;
- Prioritize access to marine resources and spaces for those whose livelihoods and wellbeing are most dependent on these;
- Minimize environmental impacts on ocean spaces and resources, using a precautionary approach;
- Engage an adaptive approach to management of ocean industries that monitors and evaluates social, economic, and environmental impacts, and develops feedback loops from these data to improve outcomes that are sustainable and socially just;
- Demand, develop, and require well-articulated and transparent objectives related to equity in ocean sector governance mechanisms, funding, and business practices;
- Explore alternate finance frameworks and partnerships for innovative strategies to reduce financial barriers for least developed countries to take advantage of emerging technologies and opportunities related to existing and new ocean sectors;
- Recognize and uphold the rights of indigenous peoples as outlined in the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP);
- Align Blue Economy planning and policies with the Sustainable Development Goals, engaging beyond SDG 14 (Life Below Water) to also include SDG 5 (Gender equality), 7 (Clean Energy), 10 (Reduced Inequality), and all other relevant SDG goals and targets.

While strong leadership is clearly needed by governments and sectors to realize the above, the role of civil society in demanding these must not be undervalued. At an individual level, we can all learn more about the ocean sectors that we are connected to directly or indirectly, and lobby for practices and support industries that are leading the way in both sustainability and social equity objectives of the Blue Economy. Getting involved, as individuals, includes sharing your thoughts, dreams, and fears about the rapidly emerging Blue Economy. This also means engaging in dialogue with elected officials, community groups, and ocean-related organizations where you live, work, and play so that the Blue Economy can continue to be shaped by a diversity of voices and experiences.

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Dr. Colette Wabnitz (she/her) is currently the lead scientist at the Stanford Center for Ocean Solutions at Stanford University, USA and Research Faculty at the Institute for the Ocean and Fisheries, University of British Columbia, Canada. Colette is a passionate and driven interdisciplinary marine scientist seeking to understand how socio-ecological systems respond to change. She is interested in co-creating strategies that optimize resilience and are equitable and sustainable. Colette draws on over 15 years of international experience focused broadly on managing biodiversity risk and achieving positive outcomes across the three pillars of sustainability: society, the economy, and the environment. In an effort to co-create research with actionable outcomes, Colette has worked in academia, intergovernmental and non-governmental organizations, and engaged widely with local communities and the private sector. Growing up in the Middle East and West Africa, Colette was exposed to international development work from an early age. This led to her interest in understanding the complexities of social-ecological systems and developing pragmatic solutions to ocean challenges that work for both people and nature.

Chapter 23
Leveraging Innovation for Ocean Conservation

Annie Brett

Our ocean is facing many threats. Climate change and other human impacts are decimating marine ecosystems. At the same time, humans need the ocean more than ever. A growing population will increasingly rely on seafood to meet critical protein needs, while our climate and natural systems are inextricably tied to and regulated by the ocean. Without a healthy ocean, our global functioning is at risk.

These risks to the ocean come at a time of promise, with new technologies enabling better methods of collecting data on the oceans, of identifying problems early, and of restoring degraded ecosystems that we did not even imagine decades ago. Technology alone will not save our oceans, but it is a crucial piece of enabling better management and ocean conservation outcomes.

Enabling Better Understanding

More data on the oceans was collected in the last decade than in the previous one hundred years combined. New technologies are rapidly expanding our understanding of ocean ecosystems. For most of history, the majority of ocean science has relied on large, ocean-going research vessels to gather data. These vessels are expensive to run and only able to reach limited areas of the ocean and are only available to the most well-funded scientific researchers.

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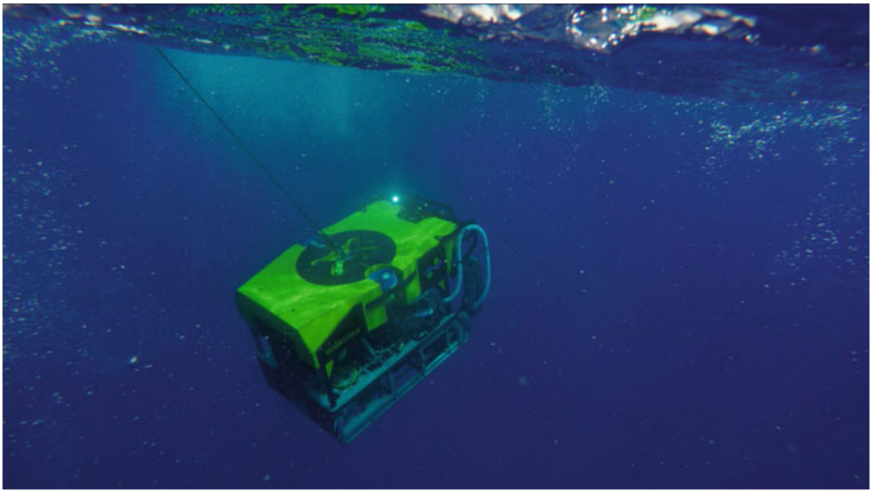
Today, technology is changing the landscape of ocean data collection. Passively powered autonomous vehicles like SailDrone are able to stay at sea for months at a time, transmitting data on new regions of the ocean back to shore through satellite. New types of low-cost sensors are being deployed throughout the oceans, on moorings and other fixed infrastructure, on shipping vessels, and even on recreational sailboats. Satellite data is being used to track illegal fishing vessels, illuminating areas of the ocean that were previously unmonitored by managers or the public. Divers and other citizen scientists can participate in reef health surveys and monitoring, expanding the reach of scientific data collection vastly. Genetic tools, like those that are able to identify DNA fragments that animals leave behind as they travel through the ocean (known as environmental DNA, or eDNA), have the potential to vastly enhance our knowledge of biological activity in the ocean.



Remote operated vehicle (ROV)—SuBastian. *Credit* Schmidt Ocean Institute

Beyond furthering our scientific understanding of the ocean, new technologies are also enabling a better understanding of how humans are using the ocean. Social media and newly developed apps allow fishermen to submit data to regulators on what fish they are catching and where. Cameras on fishing boats are replacing human observers, better allowing managers to prevent illegal fishing and at the same time collecting new data on fish population health. In some cases, these tools are being combined with new distributed ledger technologies (building on the success of Bitcoin) to both indelibly track and store data as well as provide payment to users who submit ocean related data.

New analysis tools based around artificial intelligence (AI) and machine learning leverage this new data on ocean ecosystems for better, more real-time understanding of the oceans. Algorithms drawing from big data inputs have helped to identify illegal fishing hotspots and to drive understanding of myriad ocean ecosystems. These algorithms combined with efforts to increase data access and transparency allow researchers to derive insights from many different datasets, illuminating new connections and understanding of related ecosystem trends. AI tools can complete this analysis many times faster than traditional methods, allowing managers to understand dynamic ocean conditions in near real-time and make more informed management choices. These tools have been critical in bringing together oceanographic and weather data to inform climate models and improve future forecasting.

Together, new data-collecting technologies and powerful analysis methods are creating better understanding of our ocean ecosystems and how humans use them. This understanding is critical to support sustainable ocean management in future. However, these new technology tools also allow easier and faster exploitation of ocean resources. It is essential that technological improvements are coupled with strong and forward-looking management regimes to prevent destruction to ocean ecosystems.

Supporting Effective Management

Advances in technology provide important tools to improve marine resource management beyond simply providing better and more timely information on ocean conditions. Effective management of ocean ecosystems has historically been limited by the difficulties inherent in trying to manage vast and dynamic ocean ecosystems. New technology tools can help overcome these barriers.

The sheer size of the ocean presents major challenges to management and enforcement attempts. Marine protected areas, for instance, are only effective if they are patrolled to prevent any activity not in line with MPA guidelines. Likewise, fisheries laws are meaningless if illegal fishermen are easily able to operate illegally without being apprehended. The reality though is that enforcing laws at an ocean basin scale has been far beyond the ability of any one nation, or the international community as a whole. New technologies are beginning to change this. Global Fishing Watch, for example, is providing real-time satellite tracking of fishing vessels around the world, allowing managers and the public to see where vessels are fishing. Machine learning algorithms can analyze vessel behavior from this data to identify vessels that are at high risk of illegal fishing, even if they are far away from any on the water enforcement officers. Similar technologies coupled with audio and visual on the water sensors can enable better enforcement of marine protected areas and other maritime laws. These enforcement advances are critical to supporting better marine management in future.

Arctic research. *Credit* Esther Horvath

Technological innovation is also supporting new ways of management that better reflect the reality of dynamic ocean ecosystems. Traditional fisheries management, for example, relies heavily on static geographic and temporal closures to protect fish stocks. However, many fish stocks are highly mobile over time and space, challenging the effectiveness of these traditional regimens. New technologies can enable more dynamic closures that move as fish stocks move, based on real-time data on ocean conditions and on fish catches from fishermen. These tools can also help to protect threatened species, closing areas to fishing where high concentrations of satellite tagged endangered species are present.

Creating Healthier Ecosystems

In addition to expanding our understanding of ocean ecosystems, technological advancements are also supporting active ecosystem restoration. Genetic tools are being used experimentally to identify species of coral that are more resistant to high temperatures and introduce these to areas at high risk for bleaching. Other genetic tools are being used to selectively target and limit the populations of damaging invasive species. Yet other new technologies are being deployed to help prevent plastics from entering the oceans, through river trash catching devices.

Catalyzing Broader Engagement

New technologies are also broadening participation and understanding of ocean issues. Virtual reality (VR) tools, such as those developed by The Hydrous, allow anyone with a smartphone or VR headset to experience the underwater world by simulating diving and immersing users in the midst of a vibrant coral reef, surrounded by colorful fish. Experiences like this help to raise awareness and connect even people from landlocked areas with ocean ecosystems. A proliferation of new transparency-oriented tools can allow consumers to scan QR codes on the fish they buy to see exactly how and where that fish was caught and how it has moved through the supply chain.

Citizen science technologies support the collection of scientific data by non-professionals. The organization Reef Check, for instance, has collected data from thousands of recreational diver surveys, making it one of the longest and most successful citizen science projects in the world (see Chap. 16 on Coral Reefs). Open-ROVs—low-cost, open-source submersibles—allow schools and other members of the public to explore the underwater world, gathering new information and data. These types of data collection have fueled important scientific understanding and are particularly important in the ocean, where many locations can be too difficult or costly for professional researchers to monitor frequently.

Citizen scientists are also helping to analyze new types of ocean data. For instance, historical data on climate and ocean conditions is extremely important in validating current climate models that predict climate change impacts. Ship's logs from the 1800s provide detailed climatic records but have not been included in traditional research because data is unformatted and not usable by models. The Old Weather project has harnessed a global group of citizens to digitize these records, creating a historic climate dataset that provides essential information on historical ocean conditions.

Technology for the Future of the Ocean

Together, new technologies have the potential to improve scientific understanding, promote more effective management, and increase global engagement with ocean issues. However, these technologies alone will not solve the problems facing the ocean. The history of ocean issues is mixed when it comes to technology, with many technological advancements being used for more destructive exploitation of ocean ecosystems instead of enabling better management. Many of today's technological advancements present a similar double-edged sword. This is exacerbated with many emerging technologies themselves depending on rare earth components that companies increasingly are looking to mine from deep-sea areas.

It is essential that technology advances are coupled with strong global governance regimes to ensure technologies are used to support healthy ocean ecosystems for the future. Emerging technologies have the potential to strengthen existing management and enable a new era of sustainable ocean management. We must act quickly to take advantage of this potential.

Get Involved

Everyone has a role to play in helping to leverage innovation to promote ocean sustainability and conservation over time. There are many ways to engage:

- Participate in Citizen Science projects to collect data on ocean conditions (Reef Check, Old Weather, and others).

- Use transparency tools like Global Fishing Watch to understand the global footprint of fishing.
- Explore seafood apps and digital tools in your region. For example, some organizations have an app that helps you to determine sustainable seafood choices in your area. There are also companies and supermarkets that have developed apps or have barcodes on their seafood products that allow you to track where the seafood comes from and how it was caught. Online tracking and traceability of seafood products (transparency tools) are still very rare. If this does not exist in your area, perhaps you can suggest to your local supermarket or seafood company that they develop transparency tools to help customers make informed choices.
- Support innovative solutions to ocean issues.
- Develop your own ocean innovations and submit them to global communities like UpLink Ocean.

Further Reading

High Level Panel for a Sustainable Ocean Economy, Technology, Data and New Methods of Managing Ocean Resources. https://www.oceanpanel.org/blue-papers/technology-data-and-new-models-sustainably-managing-ocean-resources

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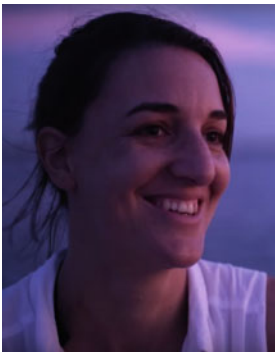

Dr. Annie Brett is an Assistant Professor of Law at the University of Florida Levin College of Law, where she teaches and writes in the areas of environmental law, ocean and coastal law, and the intersection of law and science. Her scholarship focuses on how scientific data is used in environmental decision-making, including data collected using emerging methods and technologies. In addition to legal venues, Professor Brett has published in leading scientific outlets, including *Nature*, and presented in national and international policy forums.

Prior to joining the University of Florida, Annie worked on international ocean policy for Stanford University and the World Economic Forum. She found her love of the ocean early on sailing on the coast of Maine as a child and is an accomplished mariner, recognized as the youngest female vessel captain to operate in the Pacific, and continues to participate in scientific and legal expeditions globally.

Part VI
Humans and the Ocean

Chapter 24
Oceans and Communities

Tara Sayuri Whitty

Introduction

Ocean conservation is all about humans. It seeks to protect the oceans, which really means "protect the things about the oceans that humans value." These values are threatened by human activities, which not only harm the oceans, but also harm aspects of human well-being that rely on the oceans. And conservation is a human process: We decide what is important to protect, and where and how to protect it.

Of course, we humans are not all the same. How we value the ocean, and how we choose to protect it, relies on a complex web of interconnections across the human and natural world—especially in our dizzyingly globalized world. It brings up diverse needs, values, and ways of living that can lead to differing views of how to go about protecting what we need and love about the oceans.

What We Need, What We Love, What We Stand to Lose

The benefits that we enjoy from the ocean can be called "ecosystem services." This includes services which are relatively easy to quantify and assign monetary value to, such as fisheries, which are a vital source of food and income to coastal communities around the world. "Fisheries" is a huge label, so this sector is often viewed in two major categories: small-scale fisheries and industrial fisheries.

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Small-scale fisheries generally use smaller boats and relatively low-technology gear and fish closer to shore. They are hugely important for coastal communities around the world, providing subsistence food (i.e., fishers' families eat the catch themselves) as well as food for the community and local markets. They provide income not only to fishers, but also to fish processors and fish sellers who bring the catch to different markets. They are among the most direct interfaces between oceans and human well-being in the world; as such, many examples in subsequent sections will be drawn from small-scale fisheries issues.

Credit Tara Whitty

Then, there are industrial fisheries, which are more tied to major global markets and provide seafood for consumers around the world. They can also provide economic benefits to workers and companies involved every step of the way. Similarly, aquaculture operations provide food to consumers and income to workers and businesses at different scales.

The oceans and coasts can also provide materials for building, medicinal research, technology, energy, and assorted health, beauty, and food products. The transport of products also relies heavily on shipping routes across the oceans. Across these sectors and many others—including tourism, recreation, research—people's livelihoods depend on the ocean.

Beyond providing products, the oceans also make the world more livable. From producing most of the world's oxygen, to absorbing carbon dioxide and slowing the (still too fast) process of climate change, the oceans modulate Earth's atmosphere and climate. Coastal ecosystems, such as mangroves and wetlands, can buffer coastlines against erosion and the impact of intense storms.

The oceans also provide intangible benefits, such as vital indigenous cultural practices rooted in eons of ocean-based ways of life, or the feeling of joy rushing through a surfer as they ride a wave, or the contentment you might feel knowing that there are penguins waddling around in Antarctica even though you have no prospects of going there yourself. They shape traditions, art, recreation, education, research, and so many other ways of living and learning. They make the world more beautiful, inspirational, and spiritual for us.

Altogether, the oceans contribute substantially to human well-being in diverse ways. As this book underscores, they are also under substantial threat from human impacts such as overfishing and illegal fishing, climate change, pollution, noise pollution, and destructive practices such as mining and dredging. Where oceans are under threat, the spectrum of benefits is also threatened. Some of these benefits are more vulnerable than others. And some of us are more vulnerable to the effects of losing these benefits—particularly communities who rely heavily on the ocean, such as small-scale fishing communities.

A Complex Web of Connections

Our interactions with the ocean do not occur in a vacuum. There are reasons why these interactions take place; these reasons can be called "drivers" of human activity. The benefits provided by ocean resources are the immediate drivers; fishers need income, communities and consumers need or want seafood, and there is money to be made from tourists who want to go diving.

But there are other drivers, too. These are characteristics of the social, economic, and political context that motivate or even force interactions with the ocean. Why is a fishing village so dependent on extracting fish from the sea? The underlying drivers often include scarcity of other livelihood options, limited access to education, lack of infrastructure for ecotourism, a traditional connection to the sea, or even "just" a personal preference for working on the water. For many fishers, catching enough fish has become more challenging over time with overfishing, competition with industrial and illegal fishing, climate change and more extreme weather events, and pollution. In response, fishers often intensify their fishing effort, putting in more hours and traveling farther in the hopes of catching enough fish to get by.

Credit Sally Snow

If a human-ocean interaction is changed, it sets into motion a chain of other reactions related to its drivers in the human and natural world. For example, if an endangered species of dolphin is accidentally caught (as "bycatch") in gillnets, the "simple" solution would be to ban gillnets from dolphin habitat. But what happens to the fishers? If there is another type of fishing gear they can use, then they must buy that new gear and learn how to use it efficiently. Perhaps this gear must be used in a different area so that they need to use more fuel and take more time to reach their new fishing grounds, where they might come into conflict with fishers who already fish there. Longer trips mean greater risk of accidents at sea.

Small-scale fishers often exist in chronic debt, taking loans for gear and boats at high interest rates. Switching gears might send them further into debt if they must invest in new equipment and more fuel. Perhaps they then are even less able to send their children to school, invest in other livelihoods, or pay for medical care. There might be health repercussions, such as chronic stress and depression.

Key questions include: Can they make at least the same amount of money with the new gears? Does it catch more bycatch of non-dolphin species, such as so-called "trash fish" that cannot be sold at a high value and thus are wasted? Does it catch another threatened species? Does it cause damage to the local habitat, such as seagrass or coral?

Next, consider what happens after the catch is brought to shore. If the fishers are now catching different species, or if the amount of fish caught has changed, this has repercussions for every step of the market chain. If the new catch needs to be processed differently, then local fish processors will need to adapt. Fish processors are often women, so any new or added burden in this sector will fall to women and their well-being. This will have impacts on the households of the village. If the women are working longer hours, what does that mean for childcare, or for community activities that are often planned by women?

Then, it is important to think about who is selling the products. Local vendors often bring products to nearby markets or sell them to larger-scale collectors, who then send the products to larger urban centers or abroad. If the products are transported, there might be people employed specifically for this. For the consumers, perhaps there is some significant traditional or health-based attachment to specific products. Any changes to the initial fish catch and the resulting products will affect these people down the line.

Maybe the fishers try farming instead. But maybe local farming techniques, such as the use of pesticides, are actually harmful for the environment and human health. Perhaps there is limited farmland available, so would-be farmers cut down mangrove forests to convert to farmland. If the mangroves are cleared, an important habitat for many coastal species is lost, and the village is more vulnerable to erosion and storm surge flooding. With sea level rise, coastal agricultural lands are already facing saltwater intrusion, ruining acres of cropland. So, the fishers-turned-farmers have merely shifted from one vulnerable livelihood to another.

Perhaps these fishing families move to find other livelihoods. This often involves becoming migrant laborers, an insecure existence rife with labor abuse. And this often leads to disintegration of the social fabric of the community left behind. Or perhaps an ambitious project develops the infrastructure needed to lure money-laden tourists. If not done carefully, this can come with substantial social disruption, intrusion by external investors who buy up the coastline and absorb all of the profits, and significant environmental impacts.

This scenario represents all-too-common realities for coastal communities adapting to change around the world. At times, this disruptive change is driven by conservation interests. Imagine, all of this turmoil to small coastal villages because animal lovers an ocean or a continent away earnestly wanted to save a dolphin species and pushed for a ban on gillnet fishing. These nature advocates are not the ones who shoulder the burden of their conservation wishes. They can conduct research and write reports, sign petitions and boycott seafood products, and perhaps even donate a portion of their incomes, but what they contribute does not compare to what the local communities face to lose. Their efforts might actually contribute to human suffering.

In these situations, the main goal of saving a species likely will not even be achieved. In developing countries with weak infrastructure for enforcing conservation laws, communities must be on board to comply with, monitor, and enforce conservation measures; without community support, conservation will fail. In the meantime, these coastal communities are disproportionately affected by climate change, and a catastrophe caused disproportionately by industries and consumers in wealthier nations (often the same nations in which many impassioned "save the dolphin" conservationists are based!).

These small-scale fisheries, the dolphins, and the conservationists are interwoven in the intricate and dynamic systems that define our world: natural, social, economic, and political systems. In research, these are often referred to as "social-ecological systems" or "human-natural systems." To be truly effective, i.e., to have the desired outcome without harming marginalized coastal communities, conservation must pay attention to these systems and to the possible outcomes for each conservation action. It must work meaningfully with communities to design positive conservation pathways where impacts can be diverted from a negative outcome to a mutually beneficial outcome.

Learning from and with Communities

Communities can and should be valued partners in conservation. They often possess important knowledge of the ecosystems on which they depend. "Local ecological knowledge" and "traditional ecological knowledge" can be based on years or generations of immersed observation, likely predating any formal scientific research in the area. Coastal community members often possess a genuine appreciation for the natural world around them, as well as a strong interest in sustaining not only the resources that they directly use, but also those which are nice to have around. For example, small-scale fishers often express a fondness for local dolphins, even when those animals sometimes steal fish from their nets.

Communities also are the main experts on the social context which needs to be navigated by any conservation solution. For example, what are the real limitations and avenues for adapting livelihoods? For the effectiveness of enforcement? For the possible success of proposed conservation plans? Close collaboration with communities is necessary to inform conservation decision-making in order minimize conflict and negative impacts to human well-being.

Apart from the obvious advantages of including communities, it also is an issue of rights. If any conservation project proposes to change how local resources are used, i.e., changing access to livelihoods and income, it risks infringing on the human rights and dignity of any affected communities. In several countries, indigenous peoples are also afforded special rights over their resources, and by law must be included in any planning or decision-making processes—though they often have to fight for these rights to be recognized.

Meaningfully including coastal communities in conservation requires thoughtful and respectful approaches, taking into account previous and potential future conflict between communities and conservation efforts. Communities often want to be heard, really heard, and included in the whole process from research to planning to implementation. Like any other group of humans, they want their mindsets and values understood and appreciated.

Historically, international ocean conservation has imposed the values and decisions of organizations and citizens from wealthy nations onto the natural areas and coastal communities in developing countries. This has resulted in the marginalization of many coastal communities around the world, with their voices, needs, and desires—and expertise—overlooked. Movements such as Blue Justice advocate for the rights of coastal communities to be included and respected by environmental actions. Blue Justice works to include the voices and concerns of small-scale fisheries in major ocean conservation approaches, particularly in Blue Economy and Blue Growth initiatives that tend to focus on economic facets of sustainable development without explicitly or meaningfully incorporating these communities. Thankfully, conservation has been moving toward more inclusive, participatory approaches, where communities themselves are able to take more ownership of the process and shape the outcomes. Though there is still a long way to go before this model is widespread, at least conservation is starting to shift from viewing people as *the problem* to recognizing that people are also a critical part of *the solutions.*

In Summary

Ocean conservation is not a simple story. Rather, it is entangled in intricate systems, where the fates of our favorite charismatic marine animals or seafood products are linked to questions of human well-being, rights, and equity. We are used to thinking of "conservation" in terms of daring fieldwork with awe-inspiring creatures, or high-profile international summits, or petitions and boycotts. What we really need to do more is recognize the humanity in conservation—the humanity in why we need and love the ocean, and the humanity in how we design more thoughtful, ethical, and effective conservation solutions that include coastal communities as respected leaders and partners. In a word: empathy. The future of conservation needs empathy to navigate the diverse values that we hold for the ocean in our complex world, and learning to respect and work with values beyond our own. The oceans and the humans who depend on them need more empathy.

Further Action

Our vision for saving the oceans will be stronger, more sustainable, and more socially responsible if we integrate greater empathy and awareness of diverse, complex connections to the oceans.

- Before supporting a conservation organization or foundation with your dollars, social media shares, and virtual signatures, you could contact them and ask questions such as: What are you doing to ensure local communities are actively included? How will you monitor your work's impacts on local communities? Is there an actionable plan for supporting local communities against any possible negative impacts to their way of living? If yes, how can I further support your work in that area? Can you work to feature more voices of local communities?

- Avoid characterizing communities who are in conflict with conservation as "greedy" or "ignorant," and challenge that narrative to grow more nuanced, informed, and empathic of the challenges faced by coastal communities. Encourage this more mindful way of viewing ocean conservation within your own networks to help nudge the emerging awareness of Blue Justice issues more into the mainstream consciousness.
- Recognizing and reducing other impacts on the ocean are also crucial. Global pressures on the ocean often result in pressures on coastal communities. Climate change is a huge threat to coastal communities; you could lobby for stronger climate change action and for the support of practical adaptation plans for affected coastal communities. Though it can be hard to trace, try to consume products only from socially and environmentally responsible seafood sources, including any local small-scale fisheries in your own country.
- In general, supporting and advocating for greater inclusion of marginalized groups in the ocean conservation realm will also help bring more diverse perspectives into positions of influence in the field. This could include supporting science education programs for underrepresented youth (such as Ocean Discovery Institute in San Diego), amplifying the voices of underrepresented researchers and conservation practitioners, and lobbying organizations and foundations to support career-building programs and opportunities for underrepresented groups.

Further Reading

Scientific Papers

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Kittinger JN, Finkbeiner EM, Glazier EW, and Crowder LB. 2012. Human Dimensions of Coral Reef Social-Ecological Systems. Ecol Soc 17.

Books

Eder 2009. Migrants to the Coasts: Livelihoods, Resource Management, and Global Change in the Philippines. Belmont, CA: Wadsworth Cengage Learning. *A researcher's stories from his experiences with small-scale fisheries in the Philippines. Accessible to general audiences.*

Online Resources

Too Big To Ignore: There is a wealth of resources shared by this global network for small-scale fisheries research and advocacy. toobigtoignore.net

Community Conservation Research Network: Stories and resources about local communities conserving their natural resources. Communityconservation.net

ICCA Consortium: This global network promotes “territories and areas conserved by indigenous peoples and local communities.” Iccaconsortium.org

Dr. Tara Sayuri Whitty | Keiruna Inc. I was never a child who grew obsessed with whales or dolphins or sharks. Visits to the ocean were a rare privilege, though I grew up only 15 or so miles from the coast of San Diego. It is hard to identify any particular event that led to my now 13-year-long career in marine conservation. I just earnestly wanted to make a positive difference in the world… and to travel. Conservation certainly fulfilled those criteria! I began with a focus on the behavior and conservation of mammals, later migrating into more human-focused or “social-ecological” work with my Ph.D. research at the Center for Marine Biodiversity and Conservation at Scripps Institution of Oceanography. Guided by Dr. Lisa Ballance, I dove into the world of the accidental capture (“bycatch”) of marine mammals in small-scale fisheries. Fixing this major conservation threat requires changing how fisheries operate, which often means substantial disruption to the livelihoods and well-being of coastal communities—not only unethical, but also impractical for long-term conservation success. I worked with geographers, anthropologists, economists, and political scientists to learn how to study the human side of bycatch and conservation in general. I also learned from mentors who have devoted their careers to conservation and to learning from communities, especially Dr. Louella Dolar and Dr. Danielle Kreb. Since then, I have continued to work on understanding and communicating the social side of conservation, including working for the International Union for Conservation of Nature in Myanmar and now as an independent consultant to projects in Myanmar (including guiding the local youth-led Myanmar Coastal Conservation Lab), the Philippines, and the US, guiding research, project evaluations, and training programs for more ethical, equitable, and effective conservation. It certainly does not yield the same primal thrill of my former adventures with animals in the wild. Yet I cherish this work, which has taught me so much about the realities of conservation and to be a bit dramatic, humanity. It has continually confirmed my belief that conservation can only responsibly succeed when communities are meaningfully included. On that note, my minimally-speaking autistic brother and I co-host a video podcast “The Ocean & Us” on how to bring inclusion into the world of ocean conservation.

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Chapter 25
Tourism and the Ocean

Jessica Labaja and Sally Snow

Introduction

The ocean is an invaluable resource for humanity, yet perhaps our most deliberate connection to this salty, tide-affected environment is that of leisure—a dose of fun, rest, and relaxation. Studies show (see Chap. 28) that being near the sea improves health and well-being and people who spend time in and around the ocean have an increase in feel-good hormones.

From coastal walks and beach days to diving below the surface, riding the waves, or visiting critical sites for marine wildlife, marine tourism is defined by Orams (1999) as recreational activities away from one's place of residence and focused on the ocean. It is one of the fastest growing segments of the global tourism industry, and estimates from the Organization for Economic Co-operation and Development predict that, by 2030, marine and coastal tourism could make up more than a quarter of the global ocean economy and employ over 8.5 million people. Economics may be an important driver for tourism development, but the longevity of the industry, specifically as it is dependent on natural ecosystems, can only be ensured if it is done sustainably. To achieve this and be socially beneficial to the local community, tourism must preserve the environmental and cultural integrity of the area. Tourism that does not take into account these factors is not considered sustainable and will damage the environment and local communities in the long run.

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Another term used in the industry is Ecotourism—defined by International Ecotourism Society (TIES) as "responsible travel to natural areas that conserve the environment, sustain the well-being of the local people and involves interpretation and education". However this term is now a common marketing ploy used by businesses to greenwash their operations that have no benefit for the environment and attract tourists that do not care to investigate further.

Bad tourist behaviour. Divers trampling the seabed. *Credit* Sally Snow/LAMAVE

The Impacts of Marine Tourism on the Environment and the Community

Proper management guided by sustainability principles is paramount in successful and enduring marine tourism destinations. Most nature-based tourism sites are found to first attract environmentally aware, adventure-seeking tourists who are comfortable with little to no infrastructure. As the location and its environment gain popularity with time and become more accessible with technological advancements (i.e. the self-contained underwater breathing apparatus (SCUBA); fast, cheap, and safe modes of transportation), it attracts less environmentally aware tourists who require more facilities and assistance, thus necessitating some form of development in the area and a more comprehensive management of the site. The presence or absence of an effective management structure is central to whether the marine environment and the communities that host them are positively or negatively impacted by tourism activities.

Marine tourism can contribute to the socio-economic development of the local communities. This growth can spread to its broader administrative area and the wider tourism industry. In many island nations, marine tourism is the core of their tourism industry, if not their entire economy. However, reckless commodifying of the marine environment and mismanaging its recreational use normalize harmful practises—like overcrowding and destructive behaviours such as anchoring, stepping on or kicking on corals, and vandalism—that leave the very same natural assets that support the industry and the people at risk. Negative impacts include but are not limited to: disrupting and damaging important wildlife habitats (e.g. nesting beaches for turtles, breeding areas for whales); additional pressure on local fish stocks to feed tourists; an increasing demand on infrastructure which in developing or low-income countries is still below average or non-existent; additional waste production; air and noise pollution; oil spills and chemical pollution; diverting resources like tap water to tourist sites whilst leaving the rest of the community in scarcity; and revenues not trickling down to the communities. The negative impacts are especially perceptible in mass tourism sites that according to Theng (2015), is distinguished by a disproportionately larger numbers of tourists in a site compared to the location's size and local population. Mass tourism can have negative implications to the host community's social and cultural values. The surge of tourists associated with mass tourism and recruitment of tourism workers changes community dynamics and even tribal practises as seen in the effects of the cruise ship industry in Alaska, USA. In other destinations like Jamaica, locals are being excluded from their beaches because the fees to gain entry are too expensive for them.

Although it has grown in size and stature, marine tourism is still largely determined by environmental factors and the political climate of an area. Thailand was hit by a tsunami in 2004 that devastated six southern provinces including Phuket, Pha Nga, and Krabi. In 2017, Palau's tourism industry took a blow when China banned tours to the island country because of the former's recognition of Taiwan as an independent nation. The capricious nature of the factors that the industry hinges itself upon make tourism-dependent communities extremely vulnerable when crises hit. In the first quarter of 2020, the start of the SARS-CoV-2 (a.k.a. COVID-19) pandemic immediately brought the global tourism industry to a standstill. Whilst economies worldwide endeavour to adapt, many businesses closed down or filed for bankruptcy. And yet, the full consequences to tourist-based economies are still to be known. The pandemic highlights the need to diversify economies, and the importance of healthy and resilient natural environments that provide essential ecosystem services. Thus, the recent crisis can also be an opportunity to push the travel and tourism sector to adopt science-based and more sustainable policies and practises, especially with the climate crisis in the backdrop. For example, effective carbon footprint reduction strategies in the industry will cut the amount of greenhouse gases (e.g. carbon dioxide) in the atmosphere that influence ocean acidification, changes in sea levels and water temperatures, and storm intensity amongst others, which directly impact marine tourism and the coastal communities that rely on it.

The World Economic Forum's 2019 Travel and Tourism Competitiveness Report sees South America surpassing the global average for natural resources by about 27% and Southeast Asia by about 11%. However, both regions were below average in terms of environmental sustainability. Marine tourism can assist and reinforce environmental preservation such as in the enforcement of Protected Areas. An example is the Bonaire Marine Park in the Caribbean Netherlands which is exclusively supported by tourism incomes. Management strategies include putting a carrying capacity on the number of tourists or identifying the limits of acceptable change in a site to help maintain its sustainable use. This allows management to measure and respond to the adverse effects of tourism on the social, cultural, and environmental aspects of a destination. In addition, upholding the local ways of life and protecting local livelihoods in the host destination is integral. Sustainable marine tourism is motivated by supporting grassroots economies like booking tours with local guides and patronizing local-owned establishments rather than large, international companies that may be present in these sites or those that are run by outsiders.

A big component of sustainable marine tourism is learning and interpretation. Immersion paired with accurate information on the natural environment, its importance, and its threats can be catalysts and facilitators of positive behavioural change. The experiential education that is gained in sustainable tourism sites can inspire and embolden tourists to make choices in their daily lives that positively impact ocean conservation long after they arrive back home.

Bad tourist behaviour. Anchors damage coral. *Credit* Alessandro Ponzo/LAMAVE

Marine Wildlife Tourism

Navigating the marine wildlife tourism sector can be overwhelming and difficult—from choosing well-managed sites, to understanding the difference between activities that engage with naturally occurring wildlife to those that use various stimuli like chum to attract species and create close encounters. Successful marine wildlife tourism initiatives typically target predictable, naturally occurring aggregations where animals gather in critical habitats to forage, reproduce, or give birth. When managed effectively, these initiatives can offer remarkable wildlife viewing opportunities—such as that seen in Ningaloo, Western Australia where tourism has developed to coincide with the seasonal aggregation of foraging whale sharks. Likewise, colonies of breeding seabirds attract hundreds of tourists to islands such as Skomer, off the coast of Wales, whilst tourists visiting California's Piedras Blancas Rookery can see thousands of elephant seals during peak times of the year when males battle it out for mating rights and females give birth and nurse their new pups.

These awe-inspiring interactions with wildlife in sensitive habitats can be sustainable when managed to benefit the environment and local community. They entail excellent management to safeguard the focal and non-primary species involved, the ecosystem, and local communities. Tourism sites need constant evaluation too, as violations of the local guidelines and carrying capacities, by tourists and operators alike, can happen. The desire to break rules has been amplified by the popularity of social media that prompted this appetite for "photo-worthy" encounters. This has contributed to often unlawful contact with animals and the disturbance of essential behaviour, such as in Costa Rica where tourists seeking a 'wildlife selfie' flocked to a mass nesting event of olive Ridley turtles, causing interference, and forced many turtles to abandon their egg-laying. In an effort to raise awareness on the negative impact caused by selfies and to deter tourists from handling and getting too close to wild animals the Costa Rican Ministry of Environment and Energy (MINAE) launched the campaign #StopAnimalSelfies. Even beyond the original activity, a tourist's actions within the local area continue to have an impact on the host species such as in Iceland where, post whale watching, tourists can indulge in Minke whale meat that is deceivingly marketed as a living cultural custom.

Where animals are too dispersed to ensure a high chance of an encounter, marine tourism operators have created or intensified wildlife interactions by feeding, attracting (e.g. chumming), or modifying the natural habitat. Any tourism that interferes with the natural environment is controversial as it involves introducing something new into a complex and dynamic ecosystem. This type of tourism takes many forms and is present worldwide—from the direct feeding of Indo-pacific dolphins in Western Australia to the indirect feeding of hungry manta rays using lights to aggregate zooplankton in the Maldives. On land, a popular and highly controversial tourist attraction is the head starting of turtles where hatchlings are taken from the nest and raised in captivity for several months before release. Initially promoted as a conservation strategy to aid hatchling survival, this practice is now considered a serious threat, interfering with imprinting and navigational cues, nutritional deficiencies, and behaviour modifications in turtles. Further concerns have been raised in Indonesia where poor facilities and husbandry causes infectious diseases in turtles, whilst the desire to attract tourists has seen private facilities and hotels illegally buying turtle eggs and hatchlings from nesting sites.

Another popular and controversial marine wildlife tourism sector is shark and ray tourism, which attracts more than half a million tourists each year. Scuba diving or snorkelling in protected areas offer the best natural encounters with sharks, such as those established in Palau or the Galapagos or in seasonal sites like Flora Inlet in British Columbia for encounters with bluntnose six gill sharks. Wildlife encounters that are influenced with activities like feeding and chumming are inauthentic interactions and have been shown to change the animals natural behaviour. Cage diving—where divers are submerged in a steel cage as great white sharks are intentionally attracted next to the boat using chum—stimulates a dramatic increase in activity in the sharks compared to when tour operators are absent. Elsewhere, the feeding of other species has raised a number of concerns. In the Philippines, the direct feeding of whale sharks by local tour operators has changed the sharks natural behaviour. In the Grand Cayman Island, the feeding of stingrays has intensified the number of rays aggregating in set areas resulting in long-term negative behavioural and physiological effects on the species.

Even out of the water, tourism can continue to have an impact on the marine environment. Souvenirs made or adorned with shells, whether locally made or mass-produced, are unsustainable and their exploitation is contributing to ecosystem collapse. Shells fulfil important ecological roles, such as providing food, cleaning and filtering the water, helping prevent shoreline erosion, and offering shelter or anchorage. The mollusc that lives inside the giant triton shell hunts and kills the crown-of-thorn starfish, which is a species that preys upon coral polyps and devastates coral reefs when uncontrolled. Triton shells may be protected in some countries, but very few shell species are included on international treaties such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). A lack of protection paired with the global scale of the shell trade, is fuelling the mass collection and processing of other shells that often go undocumented.

The natural world is a complex and dynamic system, composed of carefully balanced ecosystems with intricate relationships between species. When any part of this dynamic is changed, there will always be a consequence—whether one is aware of it or not, or whether there is scientific evidence or not. Applying the precautionary principle in nature tourism is always encouraged. It promotes the prevention of suspected harm to the environment and the community even when these are still faintly understood, because preserving the environmental integrity of an area is an essential component of sustainable tourism.

Credit Sally Snow/LAMAVE

Tips for Choosing Marine Tourism Destinations

The Global Sustainable Tourism Council (GSTC), states that for tourism businesses and destinations to be considered sustainable, it is required that they "enhance the socio-economic benefits to the community, respect its cultural heritage, protect the environment, and have a sustainable management strategy". Choosing such businesses and marine tourism sites supports the economic development of the place and its people without destroying its natural and cultural environments. As a visitor anywhere you can always exercise your own individual responsibility by leaving nothing but footprints and taking nothing but photographs. This includes making responsible purchasing choices by for example not buying souvenirs that are best left in their natural environment. Here are some best practises to help you decide when planning your marine excursions:

- It is community-based where the majority of the businesses and operations are locally run and most of the earnings stay locally and are spread throughout the community.
- Tourists learn about the marine environment and its importance, as well as the potential impacts of their presence and activities on marine habitats, species, and communities.
- They operate within legal boundaries (i.e. valid permits and licenses).
- They meet industry sustainability standards (e.g. Green Fins for diving and snorkelling).
- Local regulations and interaction guidelines are implemented and enforced (i.e. for marine wildlife, carrying capacity).

- Natural encounters with the marine environment and marine wildlife that are regulated.
- Strives for minimal environmental impact such as renewable energy source, waste management, and local food sourcing; promotes activities such as kayaking, surfing, paddle boarding rather than jet skiing or powerboating.
- There are monitoring and feedback mechanisms in place.

Further Reading

Sustainable standards for the diving industry and information for divers looking to support sustainable operators: https://www.greenfins.net/

Palau Pledge https://palaupledge.com/

#StopAnimalSelfies https://stopanimalselfies.org/en/home/

Sustainability and Tourism - How Can They Fit together? https://www.cms.int/en/news/sustainability-and-tourism-how-can-they-fit-together

Sustainable Tourism and Migratory Species = Convention on Migratory Species. https://www.cms.int/sites/default/files/document/cms_cop12_res.12.23_sustainable-tourism-migratory-species_e.pdf

Sustainable Marine Tourism Expert Group Meeting on Oceans, Seas and Sustainable Development: Implementation and follow-up to Rio+20, UN World Tourism Organisation 2013 https://sustainabledevelopment.un.org/content/documents/178208-%202013April_New%20York_LC.pdf

Impacts of feeding whale sharks for tourism in the Philippines: https://www.lamave.org/news/oslob-whale-sharks-scar-injury https://www.lamave.org/news/olsob-whale-shark-behaviour-change

Jessica Labaja is a conservationist and an Executive Director of Large Marine Vertebrates Research Institute Philippines (LAMAVE), the largest non-government organization dedicated to the conservation of marine megafauna and their environment in the Philippines. Growing up, she spent most weekends by the sea and dreamed of becoming a wildlife veterinarian. As she experienced more of the natural world, she became more interested and invested in protecting and preserving her country's marine resources. Having worked in conservation for almost a decade now, Jess understands that ensuring the health of the marine environment—especially in a global marine biodiversity hotspot like the Philippines—requires inclusive and interdisciplinary solutions. She started her career studying whale shark biology and ecology as well as the impacts of tourism on the species. At present, she is involved in understanding and characterizing the interactions between marine megafauna and small-scale fisheries.

Sally Snow is a Zoologist and Filmmaker and is a Director of Large Marine Vertebrates Research Institute Philippines (LAMAVE). Raised by two naturalists in West Wales, UK, Sally was drawn to the natural world from a young age. After graduating with a degree in Zoology and Psychology and inspired to increase understanding and awe of the natural world she pursued a career in natural history filmmaking. Later, concern over the plight of the oceans led her to the Philippines seeking to learn more about marine biodiversity and the actions being taken to protect it. This was the start of her journey with LAMAVE. A passionate science communicator Sally believes in conservation filmmaking as a tool for behavioural change and delivering stories that connect people and the environment. Her recent work in the Philippines uses "impact media" to address knowledge gaps (identified by research), to raise awareness in key audiences and create behaviour changes to protect marine wildlife and the marine environment. Previous campaigns have championed sustainable marine wildlife tourism amplifying messages from the grassroots level upwards.

Chapter 26
The Aquarium Trade

Natalie Barefoot

Introduction

Visiting public aquaria and seeing vibrantly coloured tropical marine fishes and charismatic marine mammals can be breath-taking, awe-inspiring, and, in some cases, life-altering. Viewing animals in-person can ignite an interest in conserving the ocean's treasures or a desire to keep marine animals in the home. Many marine biologists remember the first time they saw live sea creatures in a public aquarium or a pet store, and decided they wanted to learn more about marine conservation. For others, it arouses complicated questions and emotions related to animal welfare and the appropriate role of humans in nature.

Whilst the aquarium trade provides countless opportunities to educate and inspire, there are also aspects of the industry that warrant more in-depth investigation. How we collect, breed, and care for marine creatures may affect the animals at both individual and species levels, as well as the wild ecosystems from which they are removed. Traded animals include the highly sensitive octopus, sea stars, corals, crabs, sharks, seals, turtles, seahorses, penguins and otters, to name a few. This chapter focuses on ways the aquarium trade affects fishes and marine mammals.

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Photo courtesy of Philip and Patricia Frost Museum of Science

Fishes

Our love of the underwater world has inspired us to bring the ocean onto land and into our homes in the forms of public and personal marine aquaria. It is difficult to know exactly how many aquaria exist, but it is estimated over 2 million people enjoy the emotional and physical benefits that occur when looking into an aquarium in their home. To keep these tanks filled with brightly coloured and unusual-looking tropical fish, an estimated 20–24 million marine ornamental fish are traded per year, of which 90–95% are wild-caught.

Collection of Marine Fishes

Unlike freshwater aquarium fishes, which are mainly bred in captivity, marine aquarium fishes are mostly live-captured from tropical waters of Indo-Pacific countries such as Indonesia, Sri Lanka, and the Philippines. Fishes are then transported to retail outlets, homes, and public aquaria across the world, with consumers predominantly based in the United States, Europe, and Japan. Nearly 1500 species of marine fishes are targeted by the industry.

Divers generally remove tropical fish from reefs with nets. However, in some areas, fish are collected using harmful practises such as chemicals. For example, some collectors squirt a cyanide solution into reef crevices or near targeted fish to stun them temporarily. The use of such chemicals is linked to high mortality rates, both during and shortly after capture, and harm to the reefs (corals) themselves. Despite these techniques now being largely illegal because of their destructive nature, they are still used sometimes.

Once captured, collectors must bring fish to the surface very carefully as the changes in pressure may harm or kill them. This is because most fish have swim bladders, which are used for buoyancy control and which contain gas. As a fish ascends towards the water surface, the gas expands. Thus collectors must ascend carefully and slowly to prevent bodily damage, such as rupturing the swim bladder. Some collectors pierce the swim bladder with a needle once at the surface to relieve pressure; however, views differ as to whether this practice is a more humane method or if it causes damage beyond the swim bladder itself.

Transportation to retail outlets is stressful for fish and creates increased risks of mortality. Fish are typically placed in individual plastic bags for transportation, and shippers must take care to ensure appropriate handling. This includes adequate oxygen levels, sufficient water volume to diffuse waste produced by the fish, monitoring for disease during holding and transportation, and factors such as ensuring correct temperatures and limiting jolts and collisions.

The result of the cumulative impact from the mortality at each stage of the capture and transport process is that far more fishes need to be collected than necessary to meet actual demand. This is a significant problem. It is hard to determine the actual scope of this problem because record-keeping of the number of fish collected and which die during collection, removal, transport, and holding is sporadic. Over-collection to compensate for mortalities affects the individual species. In some cases, collectors target certain age groups or sexes, for example if the male is more brightly coloured. Live-collecting may also impact reef ecosystems, where everything is connected and over-collecting one species may reduce the ecosystem's ability to respond to stress and disturbances.

The case of the Banggai cardinalfish (*Pterapogon kauderni*) illustrates the impacts and complexities of targeting a reef species for the aquarium trade. The Banggai cardinalfish is a black-and-white tropical fish found off the Banggai Islands of Indonesia. It is a popular aquarium fish thanks to its unique shape and colouring. Over-collecting has led to decline of the species and the extirpation of some local populations. In addition, local microhabitats are degrading from other anthropogenic pressures including the removal of marine species, such as sea urchins and sea anemones, with which Banggai cardinalfish associate. This loss further fragments an already small and endemic population, providing additional obstacles to recovery in the wild. Currently, the IUCN lists Banggai cardinalfish as “endangered and decreasing”, and the United States has listed them as “threatened” under the Endangered Species Act. Ironically, and unlike many tropical fish, Banggai cardinalfish can be bred in captivity. However, complications such as disease make captive culture less economical than live-collecting.

As awareness has risen about destructive aspects of capturing aquarium fish, many countries have begun implementing collection practises that have a lighter impact on the ecosystem. Simultaneously, businesses that breed marine fishes for the aquarium industry are being developed. However, despite sophisticated aquaculture set-ups, breeding some fish species in captivity is incredibly difficult and remains elusive. Thus live-collecting will probably continue as the predominant source of fishes for trade into the future.

Release of Non-Native Fishes

Another negative consequence of the aquarium trade is the release of fishes by pet-owners who no longer are able or interested in caring for their pet. Often these fishes are released hundreds or thousands of miles from their native range, which can cause problems. Sometimes fishes purchased at retail outlets and introduced to home aquaria are not a good fit, harassing other fishes or damaging plants or corals. Alternatively, some fish are purchased small when they are suitable for the home aquaria initially but grow too large to care for (“tank busters”). Problems arise when these fishes are released into the wild. For example, the Indo-Pacific lionfish (*Pterois volitans*) was introduced to waters of the Atlantic coast of the United States where it established a large population rapidly. It then spread throughout the Caribbean and Gulf of Mexico, and now occurs along the Northwest Atlantic coast from New York down to Brazil. Lionfish is a notorious invader, competing with and preying on native fishes. No one knows for sure how this species was introduced, but it was likely the result of pet releases. Florida (USA) has a particular problem with non-native marine fish introductions. As of 2021, 44 non-native marine fish species have been recorded in Florida’s waters, most of which are popular species in the aquarium trade.

Keeping it Local

Some public aquaria focus their displays on marine species native to local waters. For example, Monterey Bay Aquarium in California (USA) is a facility that exhibits species from around the world yet centres the majority of its exhibits on local species and ecosystems. Other aquaria use methods, such as collecting marine animals from local waters and rotating animals on exhibition, especially those in touch pools, which decreases stress on individuals. There are also small and seasonal aquaria, focussed on local species that close after tourist season and return specimens to the sea.

Orca performing for a crowd. *Credit* Ingrid N. Visser, Orca Research Trust

Marine Mammals

The collection and trade of marine mammals is a complex, impassioned, and ever-evolving subject. Although humans have been entertained by and learned much about marine mammals through their captivity, maintaining these constantly-moving and socially-complex species in captive facilities inherently creates individual welfare issues and impacts populations. Yet, as we continue to increase human activities in, on, and near the ocean, we will continue to need, and arguably even have an obligation to maintain facilities that can rescue, rehabilitate, and, where appropriate, release the animals.

The Spectrum of Captivity

Marine mammals, such as polar bears, sea lions, manatees, whales, and dolphins, have specific habitat requirements that vary by species, making it difficult to convey an overarching description of their needs. Like the diverse and complex nature of marine mammals, there is a spectrum of facilities and aquaria around the world that keep marine mammals under human care ("captive facility").

At one end of the spectrum, there are for-profit companies beholden to shareholders, which employ marine mammals as entertainment for shows and interactive experiences where the animal may pull guests or boats around in the water or pose for photos. Marine mammals are kept in concrete, over-chlorinated pools, with minimal or no access to sea vegetation, natural light, or adequate space to swim. On the other end of the spectrum are not-for-profit rescue, rehabilitation, and release (RRR) facilities, as well as the first generation of sanctuaries that are opening to support the welfare and conservation of marine mammal species. Ideally, marine mammals are kept in seaside pens, away from sources of pollution (both noise and chemical) where the animals have the space and autonomy to engage in natural behaviours, swim in ocean water with access to prey and sea vegetation, and are able to experience natural light and tidal cycles. Many captive marine mammal facilities/aquaria are hybrid creations, falling somewhere along this spectrum, sometimes even using both models within the same facility or organization.

Collection of Marine Mammals

Collection of healthy marine mammals from the wild for captive displays has had negative impacts on wild populations. For example, the Southern Resident Killer Whales (SRKW) off the Pacific coast of the United States, were targeted for live captures starting in the 1960s. That resulted in reducing the wild population by at least half from deaths during captures and removals, and contributed to designating the SRKW as endangered in the United States and Canada. The SRKW population continues to struggle for survival to this day, albeit from contributions of other human-induced threats. Because we have learned that removing animals from the wild can have serious effects, many countries have enacted laws limiting wild capture and removal. In most cases, governments require scientific evidence that the removal would not have a detrimental effect on the wild population.

Live captures of cetaceans (whales, dolphins and porpoises) still occur. Currently, one of the most infamous captures takes place annually in Taiji, Japan. Cetaceans are corralled into a cove where some are selected and sold to aquaria for display and the rest are killed for consumption. During the 2017–18 drive hunt season, which targeted eight different species, 613 cetaceans were killed, 206 released (with no monitoring of survival), and 107 were sold to aquaria. This practice of drive hunts is condemned, including by the World Association of Zoos and Aquariums, which prohibits the collection of species by its members through drive hunt practises.

Marine mammals may also be collected through RRR programmes. As increasing human activities in and on the water cause more frequent injuries to marine mammals, RRR programmes perform a vital service by providing direct care as well as a deeper understanding of the stark need for conservation measures for the visiting public. Some facilities call rescued animals "patients," acknowledging their mission and the temporary care that the facility intends to provide. In instances where injured marine mammals are ill-equipped to survive on their own in the wild, aquaria may keep the animals under their permanent care. Approval from an independent committee or the government may be required for aquaria where there is a conflict of interest between deeming an animal unfit for release and inclusion in the captive facility's permanent display; especially where the facility operates for commercial profit which creates an incentive to rescue and rehabilitate, but not release the animals. Sanctuaries are currently developing as an alternative to shelter those marine mammals unable to return to the wild because of injuries or because they were born in captivity and are unsuitable for release.

Collecting marine mammals may also have a multitude of welfare consequences on these sentient species with complex family structures, and unique cultures that may include teaching behaviours, techniques, and geographical locations to the next generations. As a base illustration, it is impossible for humans to replicate marine mammal habitat, consisting of the vast and dynamic ocean, and its adjoining land or sea ice, which supports marine mammals' natural functions of travelling many kilometres a day or diving deep below the surface. The detrimental effects of restricted and/or unnatural habitats manifest, for example, in the collapsed dorsal fins of male orca, which are pulled down by gravity in captivity since they are not able to swim underwater for the lengths of time and at the depths that they would experience in the wild. The confined environment can also cause behaviours called stereotypies (repetitive movements or sounds), where a marine mammal will pace on land, log at the top of the water, chew on the sides of its tank, hit its head against a wall repeatedly, or perform other repetitive acts in order to cope with the stress of confinement.

Trade of Marine Mammals

Once an animal has been removed from the wild or has been captive-born at a facility, aquaria may engage in trade of marine mammals for various reasons. An aquarium may want to diversify the marine mammals on display for the public. Aquaria may also engage in breeding loans of animals with other facilities in order to perpetuate its collection of animals. Alternatively, facilities can trade gametes (eggs or sperm) to artificially inseminate marine mammals at their facilities to diversify gene pools. Scientists are generally in agreement that cetaceans born in captivity are not good candidates for introduction into the wild. Therefore, there are no demonstrable conservation benefits to the breeding of cetaceans in captive facilities.

Each nation manages trade of marine mammals within its borders. However, internationally, the Convention on International Trade in Endangered Species (CITES) regulates trade in endangered or threatened species and their parts. Under CITES, the movement of marine animals requires permits and certain standards to minimize "risk of injury, damage to health or cruel treatment" for the transport of animals from the sea. Evidence must also be provided to show that the trade will not be detrimental to the survival of the species nor obtained in contravention of the laws of that nation. Many marine mammals are afforded protection under CITES, for example, polar bears, manatees, dugongs, fur seals and all cetaceans. With 90% of the countries in the world participating in the regulatory scheme, CITES creates expansive coverage for protected species. However, CITES depends on individual nations for enforcement and implementation, which is performed to varying capacities and rigor and does not take into account post-transport welfare considerations such as the quality of physical space or the impacts of practises such as the breaking up of natural family structures.

Trends in Marine Mammal Captivity

Nations and facilities themselves are increasingly recognizing through the law and changes in practice that marine mammals, in particular cetaceans, should not be kept in aquaria but for narrow exceptions, mainly for the purpose of RRR. Laws implement these prohibitions through a variety of approaches including prohibiting imports, trade of gametes, public display, and/or performances, and even through regulations robust enough to effectively create logistical or economic barriers to operate the captive facility. These laws are also implemented at varying levels of government, whether national, regional or local. Aquaria themselves have also begun to voluntarily implement policies modifying their models, such as discontinuing the breeding of orca and retiring dolphins to sanctuaries.

Whilst the practice of keeping marine mammals in aquaria is beginning to shift and decline in the west, it is at the same time growing in Asia, particularly China, which is experiencing an increase in captive facilities and trade in marine mammals. China's number of aquatic theme parks grew from 39 in 2015 to over 80 in operation in 2019 with an additional 25 under construction. As of December 2020, China had over 1000 cetaceans in captivity. Representatives from both the Chinese government and Chinese aquaria industry have expressed concerns with the rapid development of the industry and reliance on import of wild-caught animals, acknowledging that regulation has not maintained an appropriate pace.

Through captive facilities, scientists have gained an enormous amount of information related to marine mammal physiology and sensory capabilities. However, we have also witnessed incredible advances in our capabilities to perform research in the wild with technology such as drones and environmental DNA. This prompts the question of whether there remains a need to use captive marine mammals for research and if so, whether that research can be limited to those in care for RRR. Furthermore, our increasing scientific understanding of marine mammals' physiological needs, sentience, cultures, complex family structures and contributions to ocean ecosystems suggests that both marine mammals and the ocean thrive when humans engage in interactions that are respectful and endeavour to keep marine mammals in the wild whenever possible.

In Summary

Aquaria submerge us into another world, through sight, sound, touch and sometimes smell, bringing us face to face with the most curious, beautiful, comical, wondrous creatures that pique our curiosity and inspire innovation. Since not everyone can—or wants to—dive into the ocean, lake or a river, aquaria provide a glimpse into a world that may otherwise be unseen. The paradox of this benefit is that the collection, trade, retention, and release of species have the ability to harm individuals and wild populations of the same incredible marine creatures we seek to understand and protect through aquaria. As knowledge and technology evolve, so too should our ethics and practises.

What Can You Do to Help?

- Think twice and do your research before purchasing any pet, so you understand the consequences of your purchase power. Was it removed from the wild? What does it eat? Will you be able to supply special foods? How big does it get? Does your tank have space to accommodate the species when it is fully grown? Can you commit the time and resources needed to care for it through its life span?
- Never release pet fish (or any pets, for that matter). Many aquarium stores will take back fish or provide information on pet amnesty programmes.
- Be informed and research before you visit a facility that keeps marine mammals captive.
- Support ethical marine mammal rescue, rehabilitation, and release facilities or sanctuaries.

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Natalie Barefoot Growing up inland, my passion for marine mammals, whales in particular, was ignited by some inexplicable, innate curiosity that drew me to watch ocean programmes, cover my bedroom walls with posters of whales, and fill my bookshelves with ocean-related books. Yet, I never thought I could work for the oceans and ocean animals as a career. Try as I might to not believe it was possible, the calling was too strong to ignore. This made my path to becoming an international ocean lawyer a winding, twisty route rather than a straight line. My work has taken me to five continents and spanned corporate law, academia, non-profits, and international governmental organizations, including the United Nations Environment Programme. Each turn in my career has allowed me to learn skills and tools that are essential to my work today. I assist and speak up for ocean creatures in a way that strives to be earth-oriented, community-inspired, and respectful of all living beings. My work focuses on legal strategies through the lens of keystone species, such as sharks and cetaceans (whales, dolphins, and porpoises), and advancing protections for wildlife and their ocean habitats. I currently tackle international ocean issues as an attorney with Earthjustice and as a volunteer with Cet Law.

Chapter 27
Marine Animal Welfare: A Growing Concern

Cat Dorey

Abstract Fishes are complex animals, with emotions, individual personalities and intelligence. Humans have wide-ranging impacts on the lives and welfare of fishes, but until recently we have given very little thought to the suffering we cause. This is beginning to change as the gap between public understanding and the science on fish intelligence closes. Governments are increasingly recognising sentience in fishes, and other marine animals like octopuses and lobsters, and are reviewing animal welfare legislation to better include them. However, with trillions of fishes killed each for food, addressing welfare in fisheries and aquaculture is complex, and fisheries in particular have largely been left in the 'too hard basket'. It doesn't have to be this way. There are solutions—we can keep feeding our growing populations whilst also ensuring fishes are treated with respect and compassion. It's a journey we need to start as soon as possible

Meet Some Clever Fishes

On the seabed of the Pacific Ocean, near the coast of Japan, a puffer fish uses his fins as plows and brushes to create furrows and ridges in the sand, and carefully places shell fragments with his mouth. After a week of non-stop sculpting, he has created a mandala of extraordinary complexity and beauty to attract himself a mate.

In the Great Barrier Reef, a grouper approaches a moray eel hidden in his lair, and shakes her head rapidly. The moray eel recognises this signal and the pair head off to hunt together. When their prey escapes into a narrow crevice, the grouper points to the hiding spot and the agile eel dives in to feast. If the prey flees into the open water, it is the grouper's turn to eat.

Note: Throughout this chapter I use the plural 'fishes'. Scientists use 'fishes' to mean multiple individuals of two or more species. In fish welfare we increasingly use 'fishes' to highlight the fact that these are multiple individual animals, distinct from their meat.

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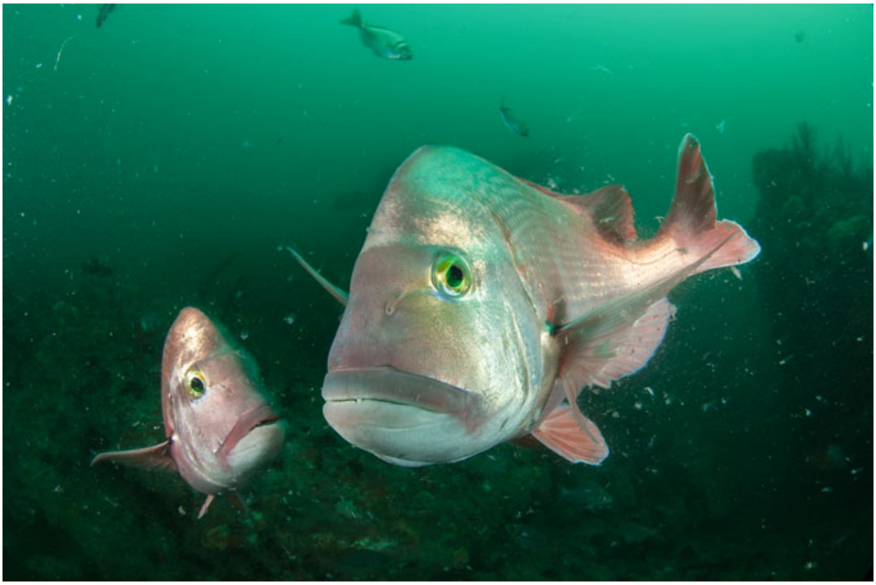
In a tank in a laboratory, a cleaner wrasse sees itself in a mirror and tries to remove some coloured gel a scientist has dabbed on her head, passing the classic self-awareness test that only a handful of birds and mammals have done before.

Self-recognition and complex behaviours like creativity, tool use, and cross-species cooperation in fishes? Yes! Many people are surprised to discover that fishes, the largest group of vertebrate animals (those with a spine), are complex animals with emotions, individual personalities, and intelligence.



Dageraad, Stilbaai, South Africa. *Credit* Steve Benjamin

Humans and Fishes—An Abusive Relationship

Humans interact with the aquatic world in many ways and, sadly, most are not positive experiences for aquatic animals, especially fishes. People often treat fishes very differently to other animals.

Many people see fishes primarily as food—they are the most consumed type of animal in the world. Recreational and sport fishing are also extremely popular. Fishes are the most popular pet in the world in terms of the total number kept, and second only to cats and dogs in terms of the number of people who keep them. Fishes are almost as common as rats and mice in laboratories, because they are increasingly popular research models in fields such as evolutionary biology and medicine.

Fishes also face mounting threats to their environments from overfishing, habitat destruction, pollution, ocean tourism, climate change and ocean acidification. Freshwater fishes in particular are amongst the most endangered animals in the world as they face multiple threats from living so close to humans.

Despite our wide-ranging impacts on the lives and welfare of fishes, until recently we have given very little thought to how we treat them. Whilst animal rights campaigns have flourished since the 1970s, these mainly focussed on land animals in industrial agriculture. When it comes to marine life, charismatic mammals like whales and dolphins and, most recently, the cheeky intelligence of octopuses have caught our attention. But for some reason we forgot the fishes. In many countries, fishes have been excluded from the definition of 'animal' under existing animal welfare legislation. Even where fishes are recognised as needing protection, fishing is often exempt from the laws.

Why have fishes been excluded? Probably because many people still think fishes lack intelligence and feelings. Some wrongly assume that because fishes were the first vertebrates to evolve, fishes of today are somehow 'lower' creatures than land animals, despite the fact they have been constantly evolving all this time. Myths about fishes' ability to think and feel abound—'The memory of a goldfish' or 'He's a cold fish' are common insults. Perhaps some people find fishes hard to relate to. They seem so different from other vertebrates, and live in a world that relatively few people can really experience.

However, with scientists turning their attention to fishes in the past few decades, we now know that not only do they feel pain, they are highly intelligent, socially sophisticated and, most importantly, capable of suffering.

Fishes Have Feelings and Are Smart

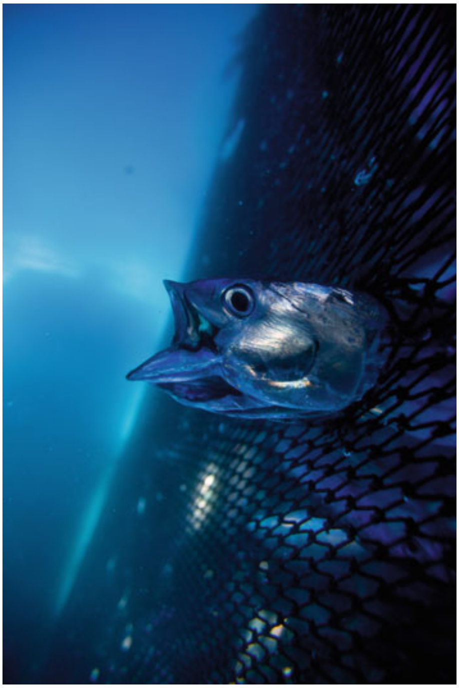
Most animals have evolved at least a basic ability to feel and avoid pain, because it keeps them safe from harm. Scientists use a range of criteria to measure the capacity of animals to feel and respond to pain, and fishes tick all the boxes. In fact, the evidence for fishes feeling pain is as good as it is for non-human mammals, and even better than that for birds, reptiles, and amphibians. When they are in pain, fishes show changes in behaviour. They can self-medicate. They are willing to make sacrifices to avoid pain, such as access to food or social companionship. Similarly, they can choose to suffer a certain amount of pain, if they decide access to food or friends are worth it. The evidence that other marine animals feel pain, such as lobsters, octopuses, squids and cuttlefishes is also comprehensive.

The ability to feel and express emotions is as important to fishes as it is to other animals. At a basic level, emotions guide animal behaviour by motivating behaviours that bring health and wellbeing, and discouraging those that have a negative impact. Emotions are adaptive, subjective, and can motivate different kinds of behaviour in different circumstances. They also act as a form of communication—a way to outwardly express an animal's current inner state. In this way, emotions help guide animals through the complex world they live in.

Scientists have identified the parts of the brain responsible for positive and negative emotional memory in fishes, and are learning how different species of fishes respond in different emotional states, which is helping to assess their welfare. Emotions affect perception and decision-making processes in animals, including humans. Animals cannot tell us what they think or feel, but changes in their physiology and behaviour can tell us a lot about their emotional state. We can measure things like the levels of the hormone cortisol in tank water that fishes, like other animals, release under stress. Scientists have shown that when a fish has a negative experience, such as a close encounter with a predator or an electric shock, they rapidly learn from that experience and present signs of fear, stress, and anxiety when later placed in the same situation—they expect the event will reoccur. Our own responses to negative emotions can help to assess the welfare status of an animal. When we feel sad our behaviour changes—we feel more pessimistic about life generally, do not want to socialise, our eating habits change, and it is hard to concentrate. The same applies to fishes—we can show they are suffering poor welfare by looking for behaviours, such as a reduced ability to learn and loss of appetite. Recent research has explained why up to 25 percent of farmed salmon do not grow properly, have abnormal behaviour patterns, and often float lifelessly near the top of tanks or cages. Both the behaviours and brain chemistry profiles of these ‘drop out’ salmon are similar to those of stressed and depressed mammals. They cannot cope with the constant and inescapable stress on the farm, and give up on life.

Finally, research shows fishes are as intelligent as most land animals. Learning and memory, social learning, innovation, culture, cooperation, reconciliation, nest building, and tool use are all behaviours used to define intelligence in animals. Not only have these been shown in fishes, but fishes have often been the leading research models used to study these abilities in animals.

This means preventing suffering is not just about taking away negative experiences, it is about providing positive experiences. Animals, including fishes, need a stimulating environment that allows them to express all their normal behaviours, from socialising to playing and exploring.



Fish dies a slow death trying to escape. *Credit* Alex Hofford/Greenpeace

Fish Welfare Is a Growing Movement

The gap between scientific reality and the public perception of fishes' intelligence and capacity to suffer is narrowing. There are an increasing number of books and media stories on fish intelligence. Conferences focussed on fish welfare are becoming more common. Established animal rights organisations are creating new initiatives for fishes, and new organisations focussed on fish welfare are springing up. The recently established Aquatic Animal Alliance now has over 100 members from six continents. Governments are increasingly recognising sentience in fishes, cephalopods (like octopuses) and decapods (like lobsters), opening doors to changes in animal welfare legislation, with Europe leading much of the work.

Some areas of our interactions with fishes are relatively easy to address—educating people in the proper care of pet fishes, developing consistent rules for the use and treatment of fishes in research and laboratories, and teaching recreational fishers how to catch and kill fishes humanely. Addressing welfare in fisheries and aquaculture, however, is more complex, and fisheries in particular have largely been left in the 'too hard basket'. It does not have to be this way.

Fishing and Farming Cause Trillions of Fishes to Suffer Each Year

Fisheries and aquaculture are an important source of food and employment, but these activities are by far the greatest human source of suffering and painful deaths, in terms of the duration, intensity, and number of fishes affected.

Official figures for fish production are reported in weight, so it is hard to know just how many individual fishes are impacted. However, based on these figures, an estimated 0.79 to 2.3 trillion individual fishes are killed annually by fisheries, with another 48 to 160 billion slaughtered in farms. In comparison, about 75 billion birds and mammals are killed each year for our dinner plates. The true figures could be as much as 50 percent higher for fisheries, because landings of small-scale and subsistence fishers are often underestimated, whilst recreational catch, discarded bycatch, and illegal catches are often not included at all. Similarly, numbers for farmed fishes include those that make it to market, not those that die along the way. The number of fishes killed will increase if aquaculture production expands as predicted.

Fishes are caught and killed using many different methods, often in violent and painful ways. Most farmed fishes are kept in environments throughout their entire lives that are nothing like their natural homes, and regularly suffer injury, illness, stress, anxiety, and depression, and when it comes to slaughter they too are killed in inhumane ways.

How can we keep feeding our growing populations whilst also ensuring fishes are treated with respect and compassion? We must recognise that the industrialisation of food production—maximising quantity whilst minimising and externalising costs—has lead to poor outcomes for the environment, people, and animals. As we begin to address climate change and the biodiversity crisis, we must rethink our food systems to address animal welfare, human rights, social justice, and sustainability. We must shift fishing and farming methods towards a better outcome for as many fishes as possible, as soon as possible.

New Directions in Fish Farming

There are some quick fixes for current aquaculture practises to reduce poor fish welfare. First, we must ban the inhumane slaughter methods commonly in use today—live gutting, asphyxiation in air or in an ice slurry, live gill-cutting, and carbon dioxide narcosis. A switch to more humane methods, like percussive (a blow to the head) or electric stunning to render fishes unconscious prior to killing, must be accompanied by further research to ensure they are optimised for the size of the fish and the species (such as determining appropriate electrical field strengths).

Stocking densities must be reduced to prevent the stress, injury and disease commonly associated with overcrowding and poor water quality. Current practises of transporting fishes from hatcheries to grow-out ponds, pens or cages, or between these during cleaning and restocking are particularly traumatic, with many fishes dying from injury and stress. Better farm design and processes can reduce transporting and handling of fishes (such as during size sorting, veterinary treatments and harvesting) to minimise stress, injury, and death.

In the longer term, as aquaculture develops and expands, we must rethink what fish species we farm, and where and how we house them. We need to shift aquaculture practises towards more natural integrated systems, in the same way that the permaculture and regenerative farming movements seek to change agricultural production—working with nature not against it. We also should encourage smaller-scale practises, at a household and community level, that allow fishes to be kept in more natural conditions, integrated with other food production, and powered from local renewable energy sources.

A significant part of this change will be to understand the welfare needs of different farmed fish species to be able to live positive lives and freely express natural behaviour. Current commercial farming methods are largely chosen for convenience, cost and scalability for industrial production rather than for ideal requirements for the chosen fish species. Farming practises either need to be redesigned based on the needs of fishes, or we need to choose fish species that are highly adaptable to current practises and with a low tendency for stress. We must also focus on farming species that do not require feed made from fishmeal and fish oil from wild fish.

This is no small undertaking—we are currently farming over 360 species of fishes, compared to around 30 species of land animals, each with their own set of unique environmental requirements and different behaviours in the wild and captivity. The Fish Ethology and Welfare Group at Faro University in Portugal, and Fair-Fish International have developed an open access 'FishEthoBase' of the latest information on fish behaviour that will allow us to better adapt current farming systems and design new ones for positive welfare outcomes. With about a third of farmed species profiles developed so far, each with major data gaps, we have a long way to go.

Rethinking Fisheries

When it comes to addressing fish welfare in fisheries, the sheer numbers affected can be overwhelming. However, addressing environmental and human rights concerns in fisheries, will often bring better welfare outcomes. We need to aim for quality over quantity in wild caught fish, and phase out fisheries practises that fail to adapt to meet the full suite of ethical standards. Redirecting harmful fishing subsidies towards redesigning smarter and kinder fishing methods would be a good start.

We must reduce the demand for wild fishes by addressing overconsumption by those who do not need to eat more animal-based protein, particularly in wealthy countries with a vast range of protein alternatives. At the same time, we must ensure catches of target species are reduced to ecologically sustainable levels, and fishing practises are developed that kill fewer non-target species and produce less waste, so fewer fishes will suffer unnecessarily.

The suffering inflicted by fisheries on individual fishes depends on the gear type, how long the gear is left in place or towed, how quickly fishes are hauled in when caught, the depths and water temperatures they come from, and how quickly they are killed once landed. To address the duration and severity of suffering, fisheries must switch to methods that catch and land fishes quickly, and develop humane handling and slaughtering practises.

Reducing bycatch to a minimum is a key step, as unwanted species of fishes and other marine animals tend to suffer the worst treatment. They are often the last to be dealt with, get kicked and trampled on, and left to asphyxiate before being thrown overboard. Sharks and rays often have their fins sliced off whilst alive. We need to develop mandatory safe-handling practises for returning sharks and rays, sea turtles, and marine mammals safely to the water.

As for farming, inhumane handling and slaughtering practises in fishing must be addressed. Fishes must be handled carefully, stunned and slaughtered quickly, or returned safely to the water if not wanted. They must not be left to suffocate on deck, or on ice or in iced water—chilling can increase their distress and cause them to suffer longer. Gill cutting and gutting fishes whilst alive must be banned.

Small scale fisheries and those fishing with lines will already be ahead of the game in addressing welfare—it is much easier to adapt to better handing and slaughtering methods when fishes are landed one by one. At the other end of the scale, we will need to totally rethink some industrial practises, in particular bottom trawling with its seabed habitat destruction and wastefully high bycatch.

It is going to be a long journey to get the changes we need, but some in the industry have already started. There are shrimp trawlers that empty their catches into a holding tank so that bycatch species can be separated from target species and returned live to the sea. A new vessel targeting Pacific cod, the FV Blue North, has been designed to address both fish welfare and crew safety. Longlines are set and hauled through a hole in the centre of the boat's hull that enables the crew to operate safely and quickly inside the vessel, rather than on the deck, avoiding the dangerous conditions of wild Alaskan seas. It also has an electrical stunning table to render fishes unconscious quickly before killing and processing.

Tuna being butchered on the deck of a longliner. *Credit* Alex Hofford/Greenpeace

Market Demand Can Drive a Better Future for Fishes

Despite the scale and complexity of the fish welfare problem, there is room for optimism—we have seen significant changes in just the past five years. Increasing concerns about the health and environmental impacts of eating meat, along with the growing vegetarian and vegan movements, can help reduce fish consumption. Plant-based seafood alternatives have a firm foothold in the meat-free marketplace, and the development of lab-cultured meat is growing, with some companies specialising in seafood.

As the demand for ethically produced food continues to rise, addressing fish welfare concerns is another way that fish traders and retailers can differentiate themselves in the market place. Certification programmes for aquaculture, like GLOBALG.A.P., Friend of the Sea, and the Aquaculture Stewardship Council, are already developing fish welfare standards—these are often an "add on" to the certifications, but it is a start.

There is also some common ground between fish welfare and seafood industry concerns. When fishes are farmed and killed quickly and humanely they are less stressed—this results in a better quality of fish with a longer shelf life. Similarly, redesigning fishing vessels and fishing gear can address crew safety as well as some fish welfare issues.

As fish behaviour and welfare experts increasingly work alongside marine conservationists, we will drive improvements that will benefit individual fishes, the marine environment, and the lives of workers in the seafood industry. We must reduce our consumption of fish, and ensure that where we do need to farm and capture fishes it is done humanely, fairly, and without the waste of trillions of fish lives. It will be a slow process of change, but we have to start somewhere.

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Dr. Cat Dorey | Marine Life Advocate I never intended to work on fishes, although some would say with my surname it was predestined! I began my career studying human disease and the immune system. My Ph.D. research focussed on salivary proteins of Australian paralysis ticks, whose bites can cause allergic reactions similar to bee stings. Colleagues in our research laboratory were studying the immune systems of tunicates, hagfish, and trout, which I found fascinating—that's where the spark was first lit. After deciding lab work was not for me, I moved to London and became a science communicator, working in medical publishing, and then as freelance writer and editor. After writing a report for Greenpeace on the health impacts of persistent organic pollutants and how they end up in newborn babies, I was asked to join the Oceans team as a researcher on a campaign for sustainable fisheries. It was a steep learning curve with all those different fish names and fishing methods, but I was—pardon the pun—hooked. I worked for Greenpeace over the next 16 years and became a specialist in fisheries and aquaculture sustainability. I then spent three years as an Independent Advisor, before joining the Australian Marine Conservation Society as a Campaign Manager, based in Sydney. About five years ago, I was invited to a workshop on the environmental, human rights, and animal welfare impacts of fisheries at Sydney University, where I am a guest lecturer. I met a group of fish behaviour biologists who taught me about fish intelligence and realised I could no longer turn a blind eye to the terrible things we do to fishes. I have made it my mission to make sure that fish welfare is considered in how we care for our oceans.

Chapter 28
Ocean and Human Health

Can We Be Well in a Sick Sea?

Easkey Britton

Introduction

The deterioration of our relationship with the natural world, especially the loss of our emotional connection with the ocean in all its wonder and aliveness is deeply concerning. Globally, water bodies and the ocean are the most degraded ecosystems in the world. Yet they continue to support us, sustaining all life on earth with food, water and the air we breathe. They regulate our climate and buffer us against the worst effects of climate change by absorbing about 90% of the excess heat already caused by greenhouse gas emissions. The ocean holds all of who we are; our evolutionary biology, our breath, our tears, our history, our waste. But now the sea is sick. Rising greenhouse gases in the atmosphere are also altering the entire chemical composition of the ocean, called 'ocean acidification', with devastating consequences for ocean species and habitats. These changes erode the ocean's resilience and increase human vulnerability to storms, flooding and sea level rise, as well as reduce food security for billions of people dependent on seafood as their primary source of protein.

All of this reinforces the dynamic, fluid and interdependent nature of our relationship with the ocean, and that we cannot be well in a sick sea.

What Is Ocean and Human Health?

As this book illustrates, the ocean does so much for us. Our health is intrinsically connected to it. As well as being home to 80% of life on Earth, providing us with essential life sustaining services, the ocean also benefits human health and well-being through recreation and relaxation. But when ocean ecosystems are degraded

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they can also pose risks to human health—through factors such as flooding and pollution. This complicated mix of threats and opportunities interact in ways we do not fully understand. Exploring these relationships is the basis for an emerging scientific discipline called "Ocean and Human Health". In essence, Ocean and Human Health (OHH) offers a lens to see, understand and experience our connection in a more holistic way.

OHH emphasizes a multi-dimensional view of health, where human health is inextricably linked to the health of the ocean. This holistic concept is nothing new. Water has been considered an active life-metaphor for millennia, with Taoist Lao Tzu writing in sixth century BC how, "Nothing in the world is softer than water. But for attacking the hard, the unyielding, it has no equal." Within indigenous cultures, such as the Maori of Aotearoa/New Zealand, certain fishing and farming practices, as well as sport and leisure activities, are dictated by the cycle of the moon and in accordance with the ebb and flow of the tides. In Victorian England, seaside holidays were recommended by physicians for respite and recovery from illness and in Ireland, holy wells continue to be important places for spiritual well-being and health promotion.

In 2020, the EU-funded Seas Oceans and Public Health project (or *SOPHIE* for short) showcased how deeply interconnected the health of people and ocean are, identifying three priority areas for OHH:

1. Sustainable seafood for healthy people, where food from the ocean is healthy, nutritious, safe, and accessible to all, while ensuring sustainability of fishing-dependent communities.
2. Blue space, tourism and well-being, where individual and community health and well-being is improved through positive interactions with healthy blue spaces that are sustainably managed.
3. Marine biodiversity, medicine and biotechnology, recognizing the value and importance of medicines from the sea that can help prevent and cure disease as well as better understanding the fundamental links between healthy, biodiverse marine environments and human health.

There is so much more we have yet to discover and learn from the ocean and marine species. With species extinction increasing at a rate unprecedented in human history, it is critical to understand and protect marine biodiversity as soon as possible; to promote a healthy and resilient ocean and to ensure conservation of these environments that can also support human health into the future.

OHH presents an opportunity for a new way of understanding our relationship with the ocean. The following explores in greater detail the therapeutic or healing qualities and potential of the ocean when we directly engage with it or experience it through recreational activities.

Credit Easkey Britton

Blue Care—The Power of the Ocean to Heal

We know that most of the earth's surface is covered by ocean and that most of the human body is composed of saltwater. We also know that there are critical linkages between water, marine ecosystems and our own health. However, the ocean and its link to human health remains overlooked and poorly understood by mainstream ocean and public health policies.

That said, there is something of a blue turn across scientific disciplines with growing interest in and recognition for the health benefits provided by the ocean, giving rise to new areas of research such as 'Blue Health'. In the last 10 years research scientists are just beginning to realize how access to and engagement with healthy marine and coastal environments, or 'blue space' can directly support, enhance and restore health and well-being in particular for more vulnerable groups. There is strong evidence that 'blue space', aquatic environments like the sea, are the most psychologically restorative of all environments for humans. This offers huge potential for novel health care interventions and health promotion when addressing, for example, the psychological distress in the wake of multiple and interrelated global crises such as a pandemic, climate breakdown and conflict.

Ocean therapy, also referred to as ‘blue care’, involves water-based activities or programs designed to assist individuals coping with mental, emotional and physical illness by accessing the ocean environment. Groups and organizations around the world are tapping into the restorative power of the ocean to tackle issues like mental health and environmental degradation in novel ways. Engaging with marine and coastal environments offers very different sensory experiences to land-based environments, with different health and well-being outcomes and benefits.

As a species, humans are more at home on the stable terrain of dry land. Crossing the threshold from the shore into the sea has a profound effect on our bodies and minds. There is strong evidence to support the health benefits of ocean therapies, especially for our emotional and psychological well-being. For example, one study described how surf therapy provides, “a chance to forget rather than focus on problems”. Feelings of presence, flow and a connection to nature were often reported by participants across various surf therapy studies. This enhanced sense of connectedness, joy and psychological well-being could, in turn, reduce dependency on anti-depressant medication. Other findings point to the health benefits from immersion in the multi-sensory qualities of the sea and how ocean therapy activities can act as a tool to experience this sensory world more directly. The changeable and unpredictable nature of the sea stimulates us in unexpected ways. Responding to the movement of the waves and learning to balance on a surfboard can help improve physical health outcomes such as mobility and reduced inflammation for amputees or those with spinal cord injuries. This, in turn, can lead to a reduction in the use of narcotics for pain management. Similarly, in other studies with swimmers and divers with physical disabilities or injuries, the sensation of floating free in saltwater was not only associated with improved mobility, heart and lung functioning but also increased feelings of self-worth. Held by the water, participants felt a sense of freedom and free from societal expectations and judgements. As one participant in therapeutic diving intervention for people with physical disabilities described: “Diving turns me back into a human being, I go down there and I have got the freedom and I’m back to being a person.”

The SOPHIE project, which engaged over 14,000 OHH experts and citizens who contributed their priorities for a sustainable future, identified the opportunity to counter the dominant narrative of the sea. Instead of the old narrative depicting the sea as risky and dangerous, a new one is created that also recognizes our marine environment as health-enabling, where our seas and coasts are celebrated for a range of health-promoting benefits. This builds on other emerging initiatives that point to a reawakening and reimagining of our ocean heritage and values, presented in the very pages of this book.

However, not all experiences of the ocean are necessarily positive and not all health outcomes are universal or beneficial. Barriers persist around water quality, safety and access to healthy environments, especially in more socially deprived communities. The sea is not only a place of healing but can represent a place of loss and tragedy.

To date, most studies on the health and well-being impacts of blue spaces are from developed nations that fail to consider the cultural aspects of our sea connection, and how this might intersect with inequalities, gender, age, race, ethnicity and other social factors that determine our health.

Restore the Ocean as a Safe and Healthy Space for All

To tap into and realize the tremendous healing potential of our ocean in a fair, just and inclusive way we need to restore the ocean as a safe and healthy space for all. Our ability to access and experience the sea in a positive way is shaped and determined by our history, culture, class, race, gender and other social structures such as political and economic systems, and the role of mainstream media. To restore the ocean as a health-enabling space we need to create enabling spaces where the illusion of separateness crumbles. Some existing initiatives creating a wave of change toward more equal opportunities include:

- INCLUSEA, an Erasmus+ funded project fostering and promoting greater inclusion and accessibility for people with physical and/or sensory disabilities in surfing in Europe.
- Liquid Therapy, the ocean therapy charity for children with autism;
- Sailing into Wellness for people recovering from addiction;
- Sea Sisters in Sri Lanka and Be Like Water in Iran, empowering women and girls with essential water-based life skills, helping to restore the ocean as a safe space;
- The paddle-outs for 'Solidarity in Surfing', initiated by Black Girls Surf, a non-profit surf performance training and coaching program for young black females, that spread around the world in protest against police brutality and racism.

These are all examples of a growing number of initiatives around the world supporting a diversity of experiences. Integrating different stories of how and why the ocean matters and its ability to heal, celebrating a more diverse, healthy and inclusive ocean.

The conversation on Ocean and Human Health must continue to tease out the complexity of the health risks and benefits for diverse groups of people from our waterways, coasts and seas. It is a conversation we need to take beyond the domain of marine sciences and into our communities, our work, our health care, and our governments. Reclaiming our connection with our watery origins in the ancient sea may not be the solution to all our global crises but it is an essential part of our human well-being and ability to flourish.

We cannot be well in a sick sea.

Credit Easkey Britton

What Can the Reader Do?

Here are some ways to deepen your connection with the ocean and enhance your well-being.

1. *Ocean breath*

   50–85% of the oxygen in the Earth's atmosphere comes from the ocean. We are always connected through our breath to the ocean. Bringing attention to breathing is one of the most direct and powerful ways to self-connect and become grounded in the present moment. The breath is the greatest connector. Ever present, it is the constant reminder of the cycle of ebb and flow, and the expansion and contraction that is life. Every second breath connects us to the sea. The breath energizes and cleanses, neutralizing biological and environmental toxins. Awareness of our breath brings us back into our body, back to now.
2. *Soothe your mind*

   Take a 'blue mind' moment. Even if you cannot get to the sea, evidence shows that simply looking at a picture or listening to the sea can calm our minds. If you take a photo next time you are by the sea, or make a sound recording, you can activate your blue mind by consciously breathing (above), while looking or listening to your recorded 'seascape'. This way, you can return to your blue mind state at any moment in your daily life, helping to soothe your nervous system.

3. *How does the sea make you feel? Why not try out this reflective practice for yourself*

   – Before going to the beach, make a note of how you are feeling.
   – While you are at the sea, or during an activity like snorkeling, swimming or rockpooling, notice what feeling is most alive in you and make a note of it (record in notebook or make a voice memo on your phone).
   – On your return, make a note of how you are feeling once again.
   – Reflect on your list of feelings and ask yourself or journal your response to the following: Did you notice any changes? Why do you think you felt the way you felt? Which elements or experiences influenced how you felt at the beach?

4. *What you can do for the ocean*

   Partner with real-world scientists by getting involved in citizen science initiatives on your next coastal visit, such as the International Coastal Cleanup, the Great Eggcase Hunt, documenting shark eggs, or record sightings of marine life for global scientific databases with your phone by downloading an app (see resources for more).

Note: These activities were adapted from my book, '50 Things to do by the Sea.'

Further Reading and Resources

Citizen Science

Ocean Conservancy's International Coastal Cleanup; https://oceanconservancy.org/trash-free-seas/international-coastal-cleanup/
The Shark Trust's Great Eggcase Hunt; https://www.sharktrust.org/great-eggcase-hunt
eOceans activity tracker and observation logger; https://www.eoceans.co

Ocean Action/Ocean Literacy

Britton, E. (2021) *50 Things to Do by the Sea.* Pavilion UK.
We Are Ocean (2018) *Accelerating Ocean Literacy in the UK*. A Report by Wild Labs, UK

Blue Care Review

Britton, E., Kindermann, G., Domegan, C., & Carlin, C. (2020). Blue care: a systematic review of blue space interventions for health and wellbeing. Health Promotion International, 35(1), 50–69. Accessed online: https://academic.oup.com/heapro/article-abstract/35/1/50/5252008

Blue Mind

Nichols, W. J. (2014). *Blue mind: how water makes you happier, more connected and better at what you do*. Hachette UK.

Oceans and Human Health

SOPHIE Consortium (2020) A *Strategic Research Agenda for Oceans and Human Health in Europe.* H2020 SOPHIE Project. Ostend, Belgium. ISBN: 9789492043894 DOI: https://doi.org/10.5281/zenodo.3696561. Accessed online: https://sophie2020.eu/wp/wp-content/uploads/2020/03/SOPHIE-Strategic-Research-Agenda.pdf
IPBES (2019) Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. E. S. Brondizio, J. Settele, S. Díaz, and H. T. Ngo (editors). IPBES secretariat, Bonn, Germany. 1148 pages. https://doi.org/10.5281/zenodo.3831673

Easkey Britton as a marine social scientist, my work is about better understanding our relationship with the ocean, and how we might heal and restore our relationship with it. As a lifelong surfer my life is lived in intimate relationship with the sea. My name, Easkey, has its origins in ancient Gaelic for fish. I am named after an important salmon river near my place of birth in Ireland that creates a famous wave or 'surf break', where the river flows into the sea. It is my father's favorite surf spot. In Irish mythology the salmon is known as *bradán feasa*, the salmon of knowledge or wisdom. To me, my name is a reminder of a deep connection and interdependence with the salmon, the river and the waves; the more-than-human world. It is a reminder of a time when the stories we told celebrated the wisdom of other species. A time when we understood how our identity was inextricably linked to the sea and how we have all been shaped and formed by the ocean. For many, the ocean remains an expanse of 'blue space'. What lies below the surface most humans may never see or experience first-hand. Indeed, much of the ocean remains unexplored, with up to two thirds of marine species still to be discovered. I had the good fortune of a childhood spent in close proximity to the coast, full of the wonder of tidal movements, the power of the sea, and fast moving weather fronts. At a very early age I learned about the life of intertidal zones from time spent exploring rock pools, before following my parents into the surf. The power of the sea to instantly bring me back to myself, to calm and restore, never ceases to amaze me. And yet, our desire to be cleansed, to wash away the stress and worries carried on land has become tainted in an ocean that is also becoming saturated with our human waste. I have directly experienced the consequences of surfing in water contaminated by untreated sewage overflow at popular surfing spots, with no warning for water-users of the risks. Unfortunately this is not an uncommon issue at many coastal bathing sites around the Irish coast, and around the world. Indeed, there are over 250 million clinical cases world-wide of gastro-enteritis and respiratory disease annually, linked to bathing in contaminated ocean water. For example plastics, including microplastics, have been detected at all depths in the ocean and may pose future health risks. Also surfers, sea swimmers and other water-users have been identified by scientists as being at risk of exposure to antibiotic resistant bacteria.

Part VII
Diversity and Inclusion in the Ocean Space

Chapter 29
Gender and the Ocean: Marine Resources and Spaces for All

Sarah Harper and Angela Martin

Introduction

The typical media image of a seafarer or crew on a deep-sea trawler is often of a tough, masculine figure. Many ocean related activities and industries have historically been, and in some cases continue to be, male dominated. However, as this chapter explores, it is essential to recognize that women participate in, contribute to, and benefit from the ocean and its related industries including fisheries, transportation, tourism, mining, research and development, among others. All of humanity is connected to the ocean in one way or another, yet substantial gender disparities exist in recognition of who's involved, to what extent, and in how the benefits are distributed.

Solving the complex challenges that have been explored throughout this book requires solutions that are suitable for the diversity of peoples that rely on ocean resources. This chapter focuses on how the gender aspect of identities affects experiences, opportunities, and consequently, management of ecosystems and resources in the ocean sector. Gender is just one aspect of a person's identity, which intersects with all of the other aspects of that person. Chapter 30 focuses on these intersectional experiences, opportunities and management within the ocean sector.

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What Is Gender?

Gender refers to psychological, social and cultural factors that shape attitudes, behaviors, stereotypes, technologies and knowledge. Gender expectations can affect your sense of self from childhood by reinforcing what is considered "gender-appropriate", according to your social and cultural context. This translates into the toys you are given as a child, the color and style of clothes you wear, your roles and responsibilities within your household, and the activities and jobs you are encouraged to pursue. These societal expectations, which can vary within and between cultures and change over time, form the basis of what we call "gender".

Gender includes three related dimensions: gender norms, gender identity and gender relations. Gender norms refer to spoken and unspoken rules in the family, workplace, institution or global culture that influence individuals. Gender identity refers to how individuals and groups perceive and present themselves within specific cultures. Gender relations refer to power relations between individuals with different gender roles and identities. Gender is a source of power (or powerlessness) and when it intersects with race, class, religion, indigeneity, marital status and /or sexuality, this power can increase or decrease. Our current understanding is that gender is fluid, non-binary and not necessarily linked to sex.

Sex refers to the biological attributes that distinguish organisms as male, female, intersex and hermaphrodite. In biology, sex describes differences in sexual characteristics that go beyond the reproductive functions to affect appearance, physiology or neuroendocrine, behavioral and metabolic systems of animals and plants. Sex and gender interact in unexpected ways. Pain, for example, exhibits biological sex differences in the physiology of signaling. Pain also incorporates sociocultural components in how women, men and gender diverse people, report symptoms, and how physicians understand and treat pain according to a patient's gender.

Context of Gender Inequality

Feminism is the belief that all people should be treated as equals. It is a response to patriarchal systems, where men receive more of the benefits related to wealth, health and power. Evidence of both current and historic patriarchal systems can be seen in the unequal distribution of power and wealth across genders in government positions, media representation, executive and leadership positions. These disparities are rooted in the belief that a person's capabilities differ according to their gender.

Gender inequality is one of the most widespread and pervasive forms of social inequality, spanning almost all geographic contexts and sectors of society. Gender norms are limiting, can be harmful and lead to gender inequalities, whereby people have different access to opportunities and resources throughout their lifetime because of their gender. Gender exclusion in relation to ocean spaces and activities affects: (1) Those dependent on ocean resources for their livelihoods, sustenance, health and well-being, and (2) Those who work in the ocean sector. These are fundamentally linked because the inclusion of gender diverse ocean users in ocean management and decision-making could translate into gender inclusivity within the ocean sector. Likewise, more diversity in the ocean sector and decision-making roles could increase awareness of needs and challenges of different genders, and therefore improve outcomes for those dependent on ocean resources.

How Gender Norms Shape the Ways That People Interact with the Ocean for Livelihoods, Sustenance, Health and Well-Being

Due to the social and cultural norms that influence how, where and to what extent different genders engage with the ocean, people of different genders may experience, interact with and benefit from the ocean differently. This results in gender-differentiated knowledge about the ocean. For example, women and men may fish differently, using different gears, targeting different species or different habitats. These differentiated practices translate into knowledge about fisheries and the ocean environment that is different between genders. Furthermore, the environmental observations and knowledge acquired is critical to understanding how these systems might be changing in light of climate change or other pressures. For example, where women make regular visits to the intertidal zone, to collect invertebrates, they generate a wealth of insights on these near shore habitats.

Gender differentiated experiences have implications for resource management and conservation. Thus, it is crucial that the knowledge, experiences and needs of the different genders are incorporated into management strategies and addressing threats to ocean health. However, women and gender-minorities have largely been under-represented in ocean leadership, which limits the likelihood that decisions will successfully reduce impacts on the ocean and the people who rely on them. For example, when women's fishing activities are not considered in marine spatial planning, and their voices not included in decision-making, poorly informed management actions may be implemented. These will negatively impact women or the resources they harvest, such as through the establishment of Marine Protected Areas that restrict their livelihood activities. Conversely, an inclusive approach that includes all actors and spaces is much more likely to both achieve conservation goals and to reduce impacts on the ability of women to bring food and income home to their families.

The Koli women of Vasai near Bombay in Maharashtra, have been selling fish for generations. *Credit* Sudhanshu Malhotra, Greenpeace

Gender Inequality in the Ocean Sector

Historically, as women in many countries were not legally permitted or had very limited options to work, formal working life was a domain exclusively for men. Women, having successfully fought for their right to work in many parts of the world, were expected to fit into these existing structures. An outcome of this relatively recent past is that, where it is necessary, workplaces generally only provide expensive equipment, tools and work-wear designed for use by men. This is the case for many industries in the ocean sector, from fishing and shipping to research and commercial diving. Many women who wish to work in those industries are often excluded on the grounds that they cannot perform at the same level as men using equipment designed for men. This is illustrative of the concept of gender equality, whereby all genders may have access to the same opportunities. Gender equity means providing the same access and opportunity that is available for men to all genders under the same conditions. This means redesigning work life and workplaces to better suit all genders.

In addition to physical workplace challenges, social barriers persist as some societies may actively discourage women from working in maritime industries due to traditional gender roles and expectations. For example, roles that require a person to be at sea for many weeks, or are perceived as dangerous, may not be compatible with social expectations of women to be the primary carer for children and other dependents. Furthermore, in workplaces dominated by one gender, particularly where field work is required, if there is not a culture of inclusivity with zero tolerance for discrimination and harassment, these workplaces can be hostile toward, and therefore struggle to keep, gender diverse employees, who leave or feel forced out by unfair treatment.

Some roles within the ocean sector are dominated by women, however these are often undervalued and far from positions of power. In coastal communities, women are often the ones organizing and advocating for change. However, these efforts and the participation of women in particular, systematically remain hidden or underrepresented because they are often informal roles or voluntary positions within the community. The result is that these efforts are not formally acknowledged, recognized or valued in the same way as a position of power. In small-scale fisheries, women have been disproportionately affected by the COVID-19 pandemic. Women, who dominate much of the post-harvest segment of fisheries value chains, often work in close proximity to one another in processing and marketing facilities, increasing their risk of COVID-19 infection. Women in this sector also tend to occupy temporary and lower-paid positions, with limited access to social protections. These protections are even more critical during lockdown times, where facilities might close temporarily or permanently.

Despite these challenges, women have made and continue to make significant contributions to advancing global ocean sustainability and governance. However there are only a few women that have gained global recognition for their contributions to ocean conservation and gender equity issues. These include marine conservation scientist Sylvia Earle; marine ecologist and advocate for science communication, Jane Lubchenco; and small-scale fisheries visionary and leader of the *Too Big to Ignore* initiative, Ratana Chuenpagdee. Equity in the ocean space is lagging and it is important to recognize that there are so many other women involved in ocean activism around the world. Often these women work without recognition. Women continue to face many barriers in science, management and in positions of power within ocean sectors and industries. Chapter 31 examines the nature of barriers faced by women in the ocean sector with examples shared by the authors of this book from their personal experiences working in this space.

Responding to Rapid Change Requires a Gender Perspective

In many contexts, women and other marginalized groups face many more challenges associated with the impacts of climate change. The COVID-19 pandemic has magnified underlying gender and social inequalities; responses to it have further entrenched many of these. Women have disproportionately been responsible for caring for vulnerable relatives, home-schooling children where schools have been closed, and have experienced increased gender-based violence. The outcome for women is reduced time, focus or ability to participate in work and political life and management decisions.

In response, we need gender responsive and inclusive policies and programs. To ensure responses to rapid change benefit all genders and avoid further entrenching gender inequalities, we need to understand gendered labor patterns. For this, there is a clear need to collect gender disaggregated data. Whether it is a global health or environmental crisis we are responding to, we need the data to be able to develop differentiated policies and responses to meet the needs of diverse populations, with particular attention to marginalized groups, including women. While the devastation caused by these crises should not be minimized in any way, they do offer an opportunity for self-reflection, for challenging the status quo, and adjusting our focus toward health and well-being, which includes our relationship to one another and with the ocean.

Transforming Policies to Advance Gender Equality for All Ocean Stakeholders

The increasingly complex challenges facing both the ocean and humanity require gender inclusive strategies to develop rapid responses at both local and global scales to reduce human suffering, reduce harm to the ocean and find solutions that are sustainable within the necessary timeframe. Gender inclusive policy development and implementation is critical to developing strategies that work for everyone, from climate change action to sustainable resource use to global pandemics such as COVID-19. Social and equity considerations are essential for a future that does not further entrench existing inequalities. The tides are changing and ocean policy is increasingly gender inclusive, but progress is slow in transforming both policy and practice. Success is often the result of many factors occurring together. Three important conditions are:

(1) A receptive policy environment laying the foundation for change,
(2) Grassroots leadership bringing forward the vision for change, and
(3) Public pressure to maintain momentum for change to be realized.

In most cases, these three conditions do not occur together, and there remain large gaps between policy and practice. Where there is success, the key ingredient is often local-level activism that resists social norms and pushes for change. As key stakeholders and as agents of change, women around the world are leading efforts to challenge social and environmental injustice related to ocean spaces and resources. For example, women of the Heiltsuk Nation, an Indigenous group on Canada's Pacific Coast, held key leadership roles that led to important transformations in Pacific herring fishery governance. Pacific herring is central to Heiltsuk identity and critical to their food supply and livelihoods, yet the previous policies excluded Indigenous peoples from important conservation and management decisions. These stories highlight the need to support women in defending ocean resources and spaces.

Governments and environmental organizations have committed to considering gender when designing programs or policies to address threats to ocean health or support ocean stakeholders. However, measures to ensure gender equality are often diluted because of lack of funding and support within governments or organizations. These measures become just a box to be ticked or a short paragraph written into proposals, rather than an opportunity to promote systemic and societal change. The measures that eventually get implemented in these instances have often not thoroughly considered impacts on the lives of women and girls. Women therefore continue to face barriers to participating in decision-making and accessing resources, including those related to health, education and livelihoods, further limiting their ability to participate in policy discussions.

Fishing community, Cape Verde. *Credit* Farah Obaidullah

Gender Inclusivity in Marine Related Industries and Spaces

There remains much to be done to improve gender balanced representation in marine industries and the decisions governing them. One strategy to incorporate gender inclusivity to the ocean sector has been to encourage governments to commit to specific targets. For example, most countries have committed to working toward the

United Nations Sustainable Development Goals, which include promoting gender equality and the empowerment of women and girls (Goal #5). Another approach involves communicating to resource managers that diversity and inclusivity are key to success. Around the world, gender diverse management groups lead to better outcomes in community managed fisheries. International efforts to recognize the importance of gender inclusivity in small-scale fisheries policy and governance, and to increase representation of women and other marginalized voices in marine conservation initiatives are ongoing. For example, women in the Seychelles are leading conservation initiatives, including mapping coral reefs and working to get plastic bags banned in the country. A third approach is to appeal to business and industry leaders by highlighting the creativity and innovation that diversity and inclusion enables in various sectors of the economy. For example, showcasing companies that have been more successful as a result of diverse employees and inclusive work environments. While these methods show some will from policy makers and business leaders, they make slow progress in practice.

In light of the COVID-19 pandemic, many governments and industry leaders are realizing the importance of environmental sustainability for social and economic aspects of society. As such, discussions of building back better are emerging. In addition, powerful social demonstrations led by black people in response to ongoing systemic racism, and by South American women in response to femicide, put a spotlight onto the importance of diversity throughout all levels of society. These protests sparked conversations around the world on the historic and continued lack of action to address systemic racism and patriarchy at the expense of black and Indigenous lives and, among these, women in particular. Systemic discrimination results in people experiencing all aspects of society differently, from policing tactics to healthcare provision to awarding research grants and the cultural icons we celebrate. These movements have made space for discussions around identities that are currently treated as secondary to the dominant demographic. With this level of attention from individuals, including members of the public, consumers and employees, many governments, charities and private sector organizations are making inclusivity a priority.

In Summary

For solutions to be effective, the diverse roles and perspectives of all people who interact with the ocean must be incorporated, across gender, age, class, ethnic, religious, cultural and other intersecting identities. This diversity is critical for success, ensuring human rights are respected and enabling innovation. Diverse voices have a much better chance of identifying the root causes of issues, which is absolutely necessary for developing workable and appropriate solutions and compromises, and ultimately success in ensuring healthy ocean ecosystems. The future of ocean conservation and management must be gender inclusive. Our perceptions of those engaged in marine-related sectors and the people leading management and conservation efforts must include the full spectrum of society, reflecting the diversity of actors involved in and beneficiaries of the ocean and its related industries.

Best Practices and Recommended Actions

Bringing this all back home, what exactly can we all do as individuals and collectively to promote gender equality and women's empowerment in ocean spaces? At an individual level, we can start by challenging harmful gender norms at home and in the spaces where we live, learn and work. As we venture out into the world, to go to classes, conferences, attend meetings (in-person or online), we can support and elevate the voices of people from under-represented genders, cultures and contexts. This step is important to ensure all perspectives and concerns are heard and respected, which we know is essential for ocean health. To promote gender equality in workplaces, we can draw attention to unfair practices, firstly in private discussions with our learning institutions or employers, and then in media articles and petitions for equitable workplaces if we see no action.

For those who work in government, science and civil society organizations, we can ensure that gender is integrated to support evidence-based policy related to the ocean. This can be done throughout the design, implementation, monitoring and evaluation of programs and policies. Gender integration includes:

- Embedding gender into research design, whereby at the minimum gender disaggregated data are collected and analyzed;
- Conducting gender analysis to better understand and mitigate differentiated impacts of ocean policies and programs; and
- Adopting gender transformative approaches that work to dismantle harmful gender norms.

Finally, as individuals, organizations or as representatives of our community (such as Women4Oceans), we can write letters, articles and give presentations to bolster support for gender integration into policy initiatives to ensure Governments work to eliminate gender inequality. For example, using the Sustainable Development Goals agreed on by the United Nations and its member countries, we can emphasize that the linkages between goal #5 (Gender equality) and goal #14 (Life under water) are critical to creating lasting change. Ocean health must be viewed as inseparable from gender equality, if ocean resources and spaces are to be managed sustainably and equitably.

The United Nations declared a special focus on ocean sustainability for the next decade. As we embark, let's make sure everyone is brought along: as ocean spaces and resources are both the responsibility and the benefit of all of humanity!

Further Reading and Resources

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Women in Seafood Industry https://womeninseafood.org/

https://www.amit-es.org/sites/default/files/pdf/publicaciones/cara_tannenbaum_2019.pdf

Dr. Sarah Harper is currently a postdoc working with Nature United and the University of Victoria to advance climate responsive management and adaption in fisheries. She grew up exploring Canada's Pacific coastline and, in developing a deep connection to the coast, has cultivated a responsibility to support the rich coastal ecosystems and cultures that have long existed here, and in coastal regions around the world. Sarah completed her Ph.D. in 2019 at the University of British Columbia's Institute for the Oceans and Fisheries, where she focused on bringing to light the contributions by women in fisheries economies around the world. Her research continues to weave together social, economic and policy dimensions of fisheries in Canada and around the world, including gender equality, Indigenous fisheries, fisheries access and licensing policies, subsidy provision and reform, among other topics. Sarah is a co-lead on the gender theme for the Illuminating Hidden Harvests project, a collaboration between the FAO, WorldFish and Duke University, and she is an instructor for the Haida Gwaii Institute where she teaches a course on fisheries co-management of the North Pacific Coast.

Angela Martin from a coastal village in Essex, England. From a young age, I developed a love for animals and nature. The sea and its hidden world of strange creatures were a huge source of curiosity for me, which led me to study marine biology. I completed a bachelor's degree at University of Portsmouth, a master's degree at University of Essex, and am now working toward a Ph.D. on coastal ecology. In between my studies, I have worked with ocean conservation organizations, government agencies that monitor pollution, and an office of the UN Convention on the Conservation of Migratory Species, which facilitated the conservation of dugongs and their seagrass habitats. Through all these experiences, I have seen, time and again, that the challenges facing the ocean are ultimately human, and so humans need to be central to the solutions we develop to conserve, restore, and enjoy nature. Being involved with Women4Oceans helps me to stay focused on supporting the diverse ocean community to thrive and continue their important work for the health of the ocean.

Chapter 30
Racial-Gender Disparities, and the Impacts of Coloniality in Ocean Science on BIPOC Women

Alvine Datchoua-Tirvaudey, Angela Martin, and Cinda P. Scott

Foreword

We recognize the breadth and width of the complexity of discussing race, ethnicity, gender, culture, and religion throughout the world. For this reason, we acknowledge the limitations of this chapter, especially as no Indigenous researcher is co-author to this chapter, due to the context in which it was commissioned. We will refer to Black, Indigenous and People of Color (BIPOC)) when speaking about structural aspects affecting all and to Black and People of Color (BPoC) when solely discussing issues pertaining to BPoC women. We further note that the text reflects the perspectives of three female researchers born and raised in Western Europe and North America (France, USA, UK), each with diverse identities and backgrounds. Alvine Datchoua-Tirvaudey (she/her) is Mixed (White/Afrodescendent) with a double-culture half-French, half-Cameroonian, born and raised in France and comes from a modest/middle-class socio-economic background. Dr. Cinda Scott (she/her) born in the United States and raised in an upper middle-class suburb of Boston, is Black with diverse ancestry. Angela Martin (she/her) is white British, born and raised in a working-class area of coastal Essex, UK and comes from a modest socio-economic background.

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Introduction

Racial-gender equity and the health of the environment, including the ocean, are inextricably linked, as effective solutions cannot be found without equally valuing all voices and forms of knowledge. This mutual dependency between human populations and ocean health highlights the need to investigate and resolve long-standing inequities. We can no longer afford to ignore the people most impacted by climate change from both participating in and co-designing its solution. Doing this requires the recognition that the continued oppression and exclusion of women in ocean science who identify as Black, Indigenous and People of Color (BIPOC) hinders our collective ability to solve global challenges. Differences in gender, ethnicity, race, sexual orientation, ability, class (etc.) affect people in every aspect of their daily lives and therefore a person's access to opportunities. On the surface, ocean science does not appear to abound in or to be related to issues of racial oppression; however, looking a little deeper, we see that this is not the case. Discussions and decisions around ocean conservation, science and policy are largely dominated by, and therefore tailored to, White male voices. When important decisions for ocean health are made or dominated by one demographic, the solutions developed are not appropriate for all and are therefore not effective. In addition, this approach to ocean science maintains the inequities of the wider society (racism, sexism, genderism, ableism, and classism). In this chapter we seek to address the following three questions:

- How do these exclusions impact our collective survival ?
- Why is it important that BIPOC women are prominent voices in the design and the implementation of the solutions to ocean challenges?
- How can you address a global crisis, when there is great imbalance in acceptance of different forms of knowledge?

Importance of Inclusivity for Collective Survival

The implications of inequity within ocean science, policy and conservation have societal impacts beyond the ocean practitioner community. Academic and political spheres do not fully value the different forms of thought, knowledge and know-how that exist.[1] Mostly Western academic knowledge is relied upon by politicians to draft and/or justify climate and ocean policies, which in turn heavily influences decisions that disproportionately impact BIPOC people. For example, the impacts of climate change are unequal in geographic, environmental, and economic terms. Worldwide, small islands and coastal communities are likely to experience the worst impacts of climate change. Many of these places have known colonization and still experience the impact of colonial heritage and neo-colonial practices. The more serious

[1] Ford, J., Cameron, L., Rubis, J. et al. 2016. Including indigenous knowledge and experience in IPCC assessment reports. *Nature Clim Change* **6**, 349–353. https://doi.org/10.1038/nclimate2954

environmental threats, such as rising sea levels, loss of biodiversity, and increased pollution not only affect the food supply and living conditions, but also make it likely that coastal communities will have to leave their homes and land. The issues with inequity here are two-fold, as (1) solutions and local actions to address climate change require culturally competent, anti-racist and decolonial literate ocean and climate scientists, practitioners and community leaders to work with and alongside those who are most affected, and value the input of these groups more highly than those without ties to local communities, land and knowledge. As we note above, this type of working often comes in contradition with some assumptions and practices in Western European and North American academia and in the political sphere; and (2) international cooperation is needed to address the drivers of climate change, as the places most affected contribute the least to emissions. Yet, the discussions and decision-making processes on climate change at the international level are dominated by the governmental representatives of former colonial powers, who will be least affected by climate change. Moreover they have the power, through financial resources and the backing of other large economies, to reduce ambition on emissions targets and stifle the urgency of calls to action from small island and coastal countries. To be sure that actions to address ocean challenges will be effective, the communities that will be affected by the decisions must be involved and consulted at every step of solution development.

Example: The Design and Management of MPAs

When people most affected by climate change and living next to the oceans are not part of the original goals of Marine Protected Areas (MPAs), conflicts may arise. Marine protected areas are one measure used by policy-makers to conserve marine life. However, their success depends on the design, implementation and continuous monitoring of the projects based on the expectations and knowledge of the communities living there.[2] When local voices are excluded from the decision-making process, the MPA will not be successful in meeting its conservation aims.

A recent study by Canovas-Molina determined that conflicts due to the establishment of MPAs will continue to persist around the world where: people feel excluded from the process; there is a lack of or constrained communication between stakeholders; there is competition between group members over the use of natural resources; and there is unequal distribution of the benefits of the MPA.[3] Recently, the UN called for the protection of 30% of the world's oceans by 2030. In the race to

[2] Bohorquez, J. 2020. 'What protecting the ocean can teach us about police brutality', *MPA News*. https://mpanews.openchannels.org/news/mpa-news/perspective-what-protecting-ocean-can-teach-us-about-police-brutality (accessed on 30/11/2020).

[3] Cánovas-Molina, A., & García-Frapolli, E. 2020. 'Untangling worldwide conflicts in marine protected areas: Five lessons from the five continents'. *Marine Policy*, 121, 104185. https://doi.org/10.1016/j.marpol.2020.104185.

increase the number of Marine Protected Areas (MPAs) worldwide, assessment of the current impact of MPAs on natural and social systems must be considered. The unique positionality of BIPOC women living on islands and in coastal areas makes them an essential voice to include at every level of the process to meet international goals on MPA coverage. Their involvement has the potential to reduce conflicts and improve success. Although many initiatives put local communities and local knowledge at the center of marine areas management (e.g., Locally Managed Marine Areas (LMMAs) in the Western Indian Ocean near Madagascar, Tanzania or Kenya, and the co-design of MPAs on GIS maps with local fishermen/women in Oceania), conservation projects or local-academic knowledge partnerships often lack a design that addresses (neo)colonial biases.[4] This is an ongoing issue, so when projects do attempt to work with local partners, there is often criticism about how it should be done.

BPoC Women's Voices Must Be Heard and Included

When they are listened to and included in decision-making, BPoC women can shift the knowledge imbalance. They not only bring perspectives that are otherwise missing, but also contribute to, support or reject early ideas. Solutions to ocean health are developed more quickly and relevantly than would be possible without their participation. Inequities persist and are reproduced in solutions put forward when BPoC women and their perspectives are not present for, or fully integrated into, the decision-making process. However, to participate fully in ocean science, BPoC women maneuver under the duress of various combinations of racism, sexism, genderism, and classism. They learn to work within a system that was never designed with their presence in mind, which also teaches that their voices are not valued or considered important.[5] But BPoC women do not have to justify their presence and should have access to contribute to ocean science in their own right. The challenges they face stem from beliefs and attitudes rooted in colonialism and deep seated racism, which continue to this day both in societies which have colonized and societies which have been colonized and fought against it. These barriers to participation are obstructive to the success of BPoC women.

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[4] Rocliffe S, Peabody S, Samoilys M, Hawkins JP. 2014. Towards A Network of Locally Managed Marine Areas (LMMAs) in the Western Indian Ocean. PLOS ONE 9(7): e103000. https://doi.org/10.1371/journal.pone.0103000; Smith, C. 2014. "Local communities playing a vital role in marine conservation", United Nations University. https://ourworld.unu.edu/en/local-communities-playing-vital-role-in-marine-conservation (accessed on 30/11/2020); Aswani Canela, Shankar. 2006. Incorporating Fishermen's Local Knowledge and Behavior into Geographical Information Systems (GIS) for Designing Marine Protected Areas in Oceania. In: Human organization 65. https://doi.org/10.17730/humo.65.1.4y2q0vhe4l30n0uj.

[5] Laland, K. N. 2020. "Racism in academia, and why the 'little things' matter" *Nature* 584, 653–654. https://doi.org/10.1038/d41586-020-02471-6

Visible and Invisible Barriers: Racial Disparity and Intersectionality in Academia

As discussed above, colonialist and capitalist systems ingrain and reproduce discrimination, including racism, but also sexism, genderism, ableism, and others.[6] The ways in which BPoC women experience intersectionality are unique to their identities and the ways in which society imposes classifications upon them.[7] Therefore, experiences engrained in inferiority, exclusivity, and non-belonging manifest in myriad ways.[8] Visible and invisible barriers to success are compounded when one has a certain pigmentation, identifies with or does not identify with a gender, religion, sexual orientation (LGBTQIA+), disability, impairment, socio-economic background, place of residence, semi-nomadic or nomadic lifestyle, mobility patterns, etc.[9]

This is exemplified via experiences of intersectional discriminations at school, lack of role models, difficulties to network, lack of support and understanding, income inequalities, inequities in progressing through higher education, and terminal degrees for instance. Although female graduates (53% in 2015 worldwide) outnumber male colleagues up to Master level (according to an UNESCO science report), the number of female researchers amounts to 28% with a low rate of BIPOC women.[10] According to the 2019 National Science Foundation report on Women, Minorities, and Persons with Disabilities in Science and Engineering, in the United States, of the 17,630 enrolled black female graduate students in 2016, 551 studied biology and only 18 ocean science, representing < 0.1% and < 0.003% of the entire enrolled science and engineering graduate student population, respectively.[11] Most professorships are held by white male professors (usually childless, or with stay-at-home partners or with childcare solutions). In the UK, only 5.3% of professors are UK nationals who identify as BIPOC and are referred to as BAME (Black, Asian and Minority Ethnic, with female and male combined) according to a University and College Union (UCU)

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[6] Kilomba, Grada. 2020. *Plantation Memories. Episodes of Everyday Racism.* Münster: UNRAST-Verlag. (6th edition).

[7] Crenshaw, Kimberle Williams.1994. 'Mapping the Margins: intersectionality, identity politics and violence against women of color', in Martha Albertson Fineman & Rixanne Mykitiuk (eds) *The Public Nature of Private Violence*, pp. 93–118 (New York: Routledge).

[8] Center of Intersectional Justice. 2019. *Intersectional discrimination in Europe:relevance, challenges and ways forward*. European Network Against Racism and Center for Intersectional Justice. https://www.intersectionaljustice.org/publication/2020-09-14-intersectional-discrimination-in-europe-relevance-challenges-and-ways-forward (accessed on 03/12/2020).

[9] Jewell, Tiffan and Durand, Aurélia. 2020. *This book is anti-racist: 20 lessons on how to wake up, take action, and do the work.* London: Frances Lincoln Children's Books.

[10] Huyer, S. 2015. "Is the gender gap narrowing in science and engineering?", *UNESCO Global Science Report Towards 2030.* https://en.unesco.org/sites/default/files/usr15_is_the_gender_gap_narrowing_in_science_and_engineering.pdf (accessed on 07/12/2020).

[11] National Science Foundation. 2019. *Women, Minorities, and Persons with Disabilities in Science and Engineering.* https://ncses.nsf.gov/pubs/nsf19304/digest (accessed on 07/12/2020).

report (2013), noting that BAME people comprise 13% of the UK population.[12] BAME is the umbrella term used for Black, Asian and Minority Ethnicities in the UK.

Dr. Cinda P. Scott SCUBA diving. *Credit* Dr. Heidi Herter

BPoC Women in ocean science born and raised in North America and Western Europe face more barriers embedded in overt and covert racism, sexism, and ableism than their White peers. The experience of sexism and racism are intertwined. It is often difficult for BPoC women to discern whether experienced rejection is based in the form of sex, gender, skin color, culture, religion, spirituality, socio-economic background or disabilities, or a combination of all. The latter aspects reveal that BPoC women feel a lack of support within academic initiatives tailored to promote gender equality.[13] Equally, programs promoting ethnic diversity tend to be dominated by BIPOC male voices. A recent study from LSE found that "gender" is prioritized over

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[12] UCU. 2013. *The position of women and BME staff in professional roles in UK HEIs*. https://www.ucu.org.uk/media/5559/Report-The-position-of-women-and-BME-staff-in-professorial-roles-in-UK-HEIs/pdf/The_position_of_women_and_BME_staff_in_professorial_roles_in_UK_HEIs.pdf

[13] Mercadante, L., Riggs, M., Byerly, V., Weems, R., & Andolsen, B. (1988). Roundtable Discussion: Racism in the Women's Movement. *Journal of Feminist Studies in Religion, 4*(1), 93–114. http://www.jstor.org/stable/25002072; Jonsson, Terese (2016): The Narrative Reproduction of White Feminist Racism. In: Feminist Review 113 (1), S. 50–67. https://doi.org/10.1057/fr.2016.2; Koyama, E. 2006. "Whose Feminism Is It Anyway? The Unspoken Racism of the Trans Inclusion Debate", pp. 698–705 in S. Stryker and S. Whittle (eds.) *The Transgender Studies Reader*. New York: Routledge.

"race" in equity measures at UK higher education institutions.[14] As such, promotion of women's rights do not apply equitably for all women, but primarily "white, middle-class women", as the *LSE British Politics and Policy Blog* states.[15] These practices significantly impact BPoC female scientists professionally, physically (e.g., additional fatigue, health issues etc.), psychologically and personally (García Peña 2022). This lack of inclusivity pushes some BPoC female scientists to respond to an overwhelming need to discuss matters pertaining to BPoC women by creating spaces to share these experiences, e.g., Black Women in Ecology, Evolution, and Marine Science (BWEEMS) in 2020.

Raising Awareness and Acting on the Sources of Inequity in Ocean Science

Many approaches to raising awareness and acting on sources of inequity in the design of ocean science research and teaching have been suggested. Formal and teaching agendas that are not grounded in equity reinforce existing forms of oppression through texts, lectures and examples, with a disproportionate effect on women and BIPOC.

> "Every semester, on the very first day of my seminar, I quiz my students to give them a sense of how knowledge and racial power intertwine. We first count how many people are in the room. Then I start by asking very simple questions: What was the Berlin Conference of 1884–5 ? Which African countries were colonized by Germany ? How many years did German colonization in the continent of Africa last ? I conclude with more specific questions: Who was Queen Nzinga and what role did she play in the struggle against European colonization ? Who wrote *Black Sin, White Masks* ? Who was May Ayim ?
>
> Not surprisingly, most of the *white* students seated in the room are unable to answer the questions, while the Black students answer most of them successfully. Suddenly, those who are usually unseen become visible, while those who are always seen become invisible. Those who are usually silent start speaking, while those who always speak become silent. Silent, not because they cannot articulate their voices or their tongues, but rather because they do not possess *that* knowledge. Who knows what ? Who doesn't ? And why ?
>
> This exercise allows us to visualize and understand how concepts of knowledge, scholarship and science are intrinsically linked to power and racial authority. What knowledge is being acknowledged as such ? And what knowledge is not ? What knowledge has been made part of academic agendas ? And what knowledge has not ? Whose knowledge is this ? Who is acknowledged to have the knowledge ? And who is not ? Who can teach knowledge ? And who cannot ? Who is at the center ? And who remains outside, at the margins ?

[14] Kalwant Bhopal & Holly Henderson (2019) Competing inequalities: gender versus race in higher education institutions in the UK, Educational Review, https://doi.org/10.1080/00131911.2019.1642305

[15] Bhopal, K. and Henderson, H. 2019. "Gender over Race? Equity and inclusion in higher education", *LSE British Politics and Policy Blog*. https://blogs.lse.ac.uk/impactofsocialsciences/2019/03/28/gender-over-race-equity-and-inclusion-in-higher-education/

> These questions are important to ask because the center, which I refer to here as the academic center, is not a neutral location. It is a *white* space where Black people have been denied the privilege to speak."
>
> Grada Kilomba. 2020. *Plantation Memories. Episodes of Everyday Racism*. Münster: UNRAST-Verlag (6th edition), (pages 25–26).[16]

When it comes to talking about climate change and ocean health, a first step is to fully understand the historical sources of rapid climate change. The history of the current climate crisis is traced back to the Second Industrial Revolution (1850–1870s), but the origin of the Second Industrial Revolution, and therefore climate change, began during colonization. The brutal and violent exploitation of people in Africa, Asia, North and South America, the Pacific, the Caribbean, the Atlantic, the Arctic, First Nations and Indigenous Peoples and the increased extraction of and dependence on fossil fuels (oil, gas, coal) and natural resources to enable growing economies are the base of industrialization, which has sustained capitalism until now.[17] Since climate change is historically founded in colonialism[18] by not addressing the coloniality of climate change, marine and climate scientists perpetuate the colonial and racist inequities that created the problem they are trying to solve in the first place. Through conscious, unconscious, visible and invisible barriers, racial biases have blinded and blurred our understanding of the origins of climate change, the ocean changes driven by climate change, and the regulatory relationships between ocean and climate.[19] Acknowledging colonialist belief systems as a factor driving climate change enables us to read more clearly through the practices of ocean science and policy. It enables more effective and inclusive recommendations within scientific communities and by policy-makers.

As ocean science is one of the core components informing climate change policies, we need to understand the extent to which knowledge is politicized and how some forms of knowledge are privileged over others.[20] Although many disciplines engage with the principles of "objectivity" and "neutrality" of the researcher, academic knowledge is anything but neutral.[21] "Any scholarship that does not convey the Eurocentric order of knowledge has been continuously rejected on the grounds that

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[16] See note 6.

[17] Wood, Lawrence. 2015. *Environmental impacts of colonialism*. In BSU Honors Program Theses and Projects. Item 119. Available at: http://vc.bridgew.edu/honors_proj/119

[18] Whyte K. 2017. 'Indigenous Climate Change Studies: Indigenizing Futures, Decolonizing the Anthropocene'. *English Language Notes*, vol. 55 (1–2): 153–162. https://doi.org/10.1215/00138282-55.1-2.153

[19] Hage, Ghassan. 2017. *Is Racism an Environmental Threat?*.

[20] Belhabib, D. Ocean science and advocacy work better when decolonized. *Nat Ecol Evol* **5,** 709–710 (2021). https://doi.org/10.1038/s41559-021-01477-1; Wilkens, Jan and Alvine Datchoua-Tirvaudey (2022), Researching Climate Justice: A Decolonial Approach to Global Climate Governance, *International Affairs*, Special issue to mark the 100th anniversary of International Affairs: 'The racialized and colonial power dynamics of academic–practitioner knowledge exchange', edited by Jasmine K. Gani and Jenna Marshall (https://doi.org/10.1093/ia/iiab209).

[21] Santos, Vívian Matias dos. 2018. 'Disobedient notes: Decoloniality and the contribution to the feminist critique of science'. *Psicologia & Sociedade*, 30, e200112. https://doi.org/10.1590/1807-0310/2018v30200112

it does not constitute credible science. Science is, in this sense, not a simple apolitical study of truth, but the reproduction of racial power relations that define what counts as true and in whom to believe", writes Grada Kilomba in her book *Plantation Memories*.[22] Pretending the contrary is risky, for we lose our capacity to think critically about the history of this knowledge. Indeed, the colonial heritage of academic science is still very present in our collective imaginary, vocabulary and daily routines. In times of pressing need for long-term climate solutions, the likelihood of engaging a larger number of people might be greater if all forms of knowledge were equitably consulted.[23]

Impacts on Students, Future Scientists, and Society

Should educators and students not be aware of ocean inequity, it gives the impression that formerly colonized places might have no history prior to colonization, as well as no knowledge, no expertise and therefore no contribution to make to global knowledge on oceans and climate. Approaches to teaching, research and community building in academia reinforce long-standing racist stereotypes, discrimination against BIPOC identities, cultures, intelligence, and skills.[24] It leads to the assumption that ocean science studied, researched and taught in North American and European universities is universal, includes everyone and represents everything we know for now about oceans.[25] However, the current implementation of environmental goals developed by the Western world in places where they do not solve problems suggests

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[22] See note 4.

[23] De Vos, Asha. 2020. 'The Problem of 'Colonial Science'. Conservation projects in the developing world should invest in local scientific talent and infrastructure', *Scientific American*. https://www.scientificamerican.com/article/the-problem-of-colonial-science/ (accessed on 09/09/2021); Artelle K. A., Zurba M., Bhattacharyya, J, Chan, D: E, Brown, K, Housty, J, Moola, F. 2019. 'Supporting resurgent: Indigenous-led governance: A nascent mechanism for just and effective conservation', Biological Conservation, Volume 240. https://doi.org/10.1016/j.biocon.2019.108284.(accessed on 30/11/2020); Bianco, N., Chiblow J, Dellavilla M., Hussain N., Latulippe N., Masood A, Purushuttam S., Shafik M. 2018. *Indigenous Environmental Justice Annotated Bibliography A working document presented by the Indigenous Environmental Justice Project*. https://yorkspace.library.yorku.ca/xmlui/bitstream/handle/10315/37520/IEJ-Annotated-Bibliography-june-2018.pdf?sequence=1&isAllowed=y (accessed on 07/12/2020).

[24] Saskia Vermeylen (2019) Special issue: environmental justice and epistemic violence, Local Environment, 24:2, 89–93, https://doi.org/10.1080/13549839.2018.1561658

[25] Richardson, W. J. 2018. ' Understanding Eurocentrism as a Structural Problem of Undone Science', pp. 231–242 in Bhambra, G. K., Gebrial D. and Nişancıoğlu K. 2018. *Decolonising the University*. London: Pluto Press. https://library.oapen.org/bitstream/handle/20.500.12657/25936/1004145.pdf?sequence=1&isAllowed=y [free ebook].

Pailey, R. N. 2019. "How to truly decolonise the study of Africa", *Aljazeera*. https://www.aljazeera.com/opinions/2019/6/10/how-to-truly-decolonise-the-study-of-africa/ (accessed on 07/12/2020).

not.[26] Furthermore, it does not represent what people need and want. We tend to think that all conservation programs are good. However, this is not the case.[27] Some ocean conservation projects are harmful to the people living near the oceans. For example, the *First Draft of the post-2020 Global Biodiversity Framework* suggests to widen the number of protected areas to cover "30% of land and sea areas" by 2030.[28] A working paper 'Protecting 30% of the planet for nature: costs, benefits and economic implications' by Waldron et al. looked at whether and how the goals are implementable economically. In *An Open Letter to the Lead Authors of 'Protecting 30% of the Planet for Nature: Costs, Benefits and Implications*,[29] 31 scholars called out the lack of criticism of that analysis, namely, about the effects of the economic suggestions and the colonial-driven mindset of the solutions (e.g., protected areas taking away fishing areas, loss of access to resources, acculturation effect and impoverishment through reliance on tourism). The working paper was developed by people at institutions-based mainly in Europe, America, and Australasia who might not be impacted by the changes and without consultation of people whose land and seas are targeted by the 30% goal. However, the sites identified as best to be protected are estimated to affect 300 million people, many of whom are Black, Indigenous and People of Color.

The colonial approach to ocean science wiped out the presence of local communities from oceans in the Western collective imagination and replaced it with a view of oceans as empty stretching seascapes.[30] One also knows that ocean science exists within, has participated in and upholds colonial and imperialist practices, from sea explorations to exploiting local knowledge.[31] These practices remain today in various forms. For example, contributors who help with the science are not called "scientists" and are often not named as authors of academic work, despite having substantially contributed to the research. Thus, local fishers, rangers, community groups, volunteers or others who help with data collection become invisible in the scientific record.[32]

In the current system, academic success relies on the number of research publications and their subsequent citation (Merschel et al. 2022). For example, publications

[26] Murphy, A. 2019. Conservation's Biggest Challenge? The Legacy of Colonialism (Op-Ed).https://www.livescience.com/amp/65507-conservation-colonialism-legacy.html (accessed on 30/11/2020).

[27] Mbaria, J. and Ogada, M. 2016. *The Big Conservation Lie*. Lens & Pens Publishing.

[28] Convention on Biological Diversity. 2021. *First Draft of the post-2020 Global Biodiversity Framework*, UNEP. https://www.cbd.int/doc/c/abb5/591f/2e46096d3f0330b08ce87a45/wg2020-03-03-en.pdf (accessed on 08/09/2021).

[29] Open Letter to Waldron et al. (Agrawal et al.). 2021. 'An Open Letter to the Lead Authors of 'Protecting 30% of the Planet for Nature: Costs, Benefits and Implications.' https://openlettertowaldronetal.wordpress.com/ (accessed on 08/09/2021).

[30] Hofmeyer, I. 2018. "Oceans as empty spaces? Redrafting our knowledge by dropping the colonial lens", *The Conversation.*

[31] Dodeman, A. and Pedri, N. 2020. *Negotationg waters: seas, oceans, and passageways in the colonial and postcolonial world*. Vernon Press.

[32] Rohan Deb Roy. 2020. "Decolonise science – time to end another imperial era", *The Conversation.* https://theconversation.com/decolonise-science-time-to-end-another-imperial-era-89189/?xid=PS_smithsonian

increase an academic´s chances to be included in the syllabi of ocean science courses, or to be invited to global ocean policy conferences. It is in these spaces that scientists can use their voice and have a lasting impact. For BPoC women, many of whom live in places with limited access to publishing their work and/or must rely on foreign or incoming researchers to publish, it effectively creates additional invisible barriers to their having a successful career as a scientist. As such, those in the realm of ocean science should challenge and change the way they teach, learn, research and administer education within academic spaces and particularly when out in the field.[33]

Dr. Cinda P. Scott teaching in the mangroves

[33] Cull, I., Hancock, R.L.A., McKeown, S., Pidgeon, M. & Vedan, A. 2018. *Pulling Together: A Guide for Front-Line Staff, Student Services, and Advisors.* Victoria, BC: BCcampus. [available as free ebook: https://opentextbc.ca/indigenizationfrontlineworkers/ (accessed on 05/12/2020).

Take Away Points: What Needs to Happen?

For those who consider it a goal to inform ocean policy-making, act in ocean conservation, and those who teach, train or communicate marine science and ocean health, it is essential to connect the dots between the coloniality of our academic knowledge, ocean worldviews, laws and forms of governance (Wilkens and Datchoua-Tirvaudey 2022). Simultaneously, informed and concrete actions on implicit and explicit gender-racist biases are required, including in knowledge production, research-publishing-teaching practices, the recruitment of early career researchers and professors, supervision, and mentoring.[34] In that respect, this chapter highlights how BPoC women, with regard to their diverse intersectionalities carry an unequal burden.

Ultimately, we believe that every person, whether a student, researcher, teacher, practitioner, or administrator in ocean science has the responsibility to eliminate racist practices.[35] Dismantling the reproduction of racial and gender disparities requires active participation.[36] This begins with questioning how we continue to engage in colonial scientific practices and how we are indoctrinated into these.

- *How do these exclusions impact our collective survival?/Why is it important that BIPOC women are prominent voices in the design and the implementation of the solutions to ocean challenges?*

  Racism and sexism are currently systemically embedded in colonialist structures and shape societies. The outcomes of colonialist systems not only include environmental degradation and climate change, but exclusion of non-Western forms of knowledge from global decision-making fora. The burden of systems built on coloniality falls unequally and most severely impacts BIPOC women. But in the end, the exclusion of BIPOC women disadvantages us all, for they are key players in putting forward inclusive solutions with which more people can identify and follow to address climate change and ocean health.
- *How can you address a global crisis, when there is great imbalance in acceptance of different forms of knowledge?*

  Ocean science and science as a whole are not immune from the effects of racist and discriminatory practices. It is imperative that those working in ocean science actively engage and participate in dismantling and correcting these systems. There is a growing expectation from students, researchers and civil society in North America and Western Europe to offer courses, readings, teaching, studying,

[34] Johnson, A., M.J. Huggans, D. Siegfried, and L. Braxton. 2016. Strategies for increasing diversity in the ocean science workforce through mentoring. *Oceanography* 29(1):46–54, http://dx.doi.org/10.5670/oceanog.2016.11.

[35] Shutack, Corinne. 2017. "103 Things White People Can Do for Racial Justice". https://medium.com/equality-includes-you/what-white-people-can-do-for-racial-justice-f2d18b0e0234 (accessed on 05/12/2020); Ashlee, K. 2017. "Overcoming the Fear of Being Called a Racist: White Student Affairs Professionals Working for Racial Liberation". http://convention.myacpa.org/houston2018/overcoming-fear/ (accessed 05/12/2020).

[36] Kendi, Ibram X. 2019. *How to be an Anti-Racist. Random House*; Kiddle, R. and Elkington, B. 2020. *Imagining Decolonisation.* Wellington: Bridget Williams Books.

research methods and approaches, which are open, inclusive and speak to the diversity of people living in Europe and North America. Both the #rhodesmustfall movement in 2015 (from the University of Capetown which spread to UK universities) and the Black Lives Matter movement (throughout the United States and the world), among other long-lasting initiatives, have brought new awareness to the importance of dismantling systemic racism and ending forms of oppression. BIPOC women (and all people) must be able to participate fully in ocean science, in designing solutions for climate change, and ultimately securing ocean health and survival of the communities that depend on it.

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Alvine Datchoua-Tirvaudey is a PhD candidate at the University of Hamburg. She has worked from 2019 until 2022 as a Research Associate for the Cluster of Excellence Climate, Climatic Change and Society (CLICCS) in the Center for Earth System Research and Sustainability (CEN) at the University of Hamburg, Germany. Her PhD focuses on dynamics of climate governance and ocean governance, especially the climate-ocean nexus and its related justice claims. Her research also includes contributions to the Research Group Climate and Security (CLISEC) at the Institute of Geography (University of Hamburg). She graduated from the University of Aberdeen in 2018 with a Degree of Master of Arts in Geography and International Relations. Her expertise revolves around interdisciplinary aspects of climate change, a topic which she has been actively engaging with since her Erasmus+ exchange at the University of Oslo in 2015–2016 as part of her studies, with following internships and research initiatives.

Angela Martin from a coastal village in Essex, England. From a young age, I developed a love for animals and nature. The sea and its hidden world of strange creatures were a huge source of curiosity for me, which led me to study marine biology. I completed a bachelor's degree at University of Portsmouth, a master's degree at University of Essex, and am now working toward a PhD on coastal ecology. In between my studies, I have worked with ocean conservation organizations, government agencies that monitor pollution, and an office of the UN Convention on the Conservation of Migratory Species, which facilitated the conservation of dugongs and their seagrass habitats. Through all these experiences, I have seen, time and again that the challenges facing the ocean are ultimately human, and so humans need to be central to the solutions we develop to conserve, restore, and enjoy nature. Being involved with Women4Oceans helps me to stay focused on supporting the diverse ocean community to thrive and continue their important work for the health of the ocean.

Cinda P. Scott received her Ph.D. in 2009 in Marine Biology and Fisheries with a focus on molecular evolutionary genomics from the Rosenstiel School of Marine & Atmospheric Science at the University of Miami. Her work has included teaching and lecturing, administrative and grants management, and scientific research. Since 2014, she has led The School for Field Studies, Center for Tropical Island Biodiversity Studies program in Bocas del Toro, Panamá where she currently serves as Center Director. She manages a team of faculty, staff and students who are dedicated to understanding anthropogenic impacts of tourism on the natural environment of Bocas del Toro. Her current research examines the health of mangrove ecosystems and the cultural valuation of mangroves throughout the Bocas del Toro Archipelago in addition to maintaining interests in marine protected areas, coral reef ecology and conservation biology. You can follow her adventures around the world on her website at www.cindaseas.world.

Chapter 31
Lived Experiences: Editors' Note

Farah Obaidullah and Lauren V. Weatherdon

In crafting this book, we sought a diverse group of authors across cultures, geographies, and disciplines. We invited women from the Women4Oceans (W4O) network, which offers a platform connecting over 4000 women and 400 ocean experts operating in 75 countries around the world. For this book, some 50 experts were approached and invited to contribute. Many had to decline for various reasons, whilst others had to withdraw mid-production. The writing of this book fell during a difficult time, amid a global pandemic. Women whose voices would have strengthened the chapters in this book told us they were unable to participate due to COVID-related stress, lack of employer support, or time constraints associated with caring responsibilities, particularly towards children. Those who were able to contribute to this book offer diverse and often underrepresented (i.e. excluded by mainstream) perspectives across disciplines, including natural and social scientists, geographers, governance experts, ocean conservationists, and campaigners.

The chapters in this book help to raise awareness across the broad spectrum of issues facing the ocean from climate change to overfishing and pollution, highlighting the research and actions that have occurred around the world. It also explores the many ways we interact with the ocean, including how gender and other aspects of identities

This book is about turning the tide on the crises facing our oceans—from climate change to overfishing—by improving ocean literacy and raising awareness of actions that can improve ocean health. Yet behind these topics, there is another set of important issues that were revealed through our community of authors. Whilst writing *The Ocean and Us*, we discovered that aspects of our lived experiences were shared and that both visible and invisible barriers continue to prevent women's voices from being heard.

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affect experiences, opportunities, and consequently, management of ecosystems and resources in the ocean sector. However, for every person who contributed to this book, there is a personal journey of challenges and obstacles they have had to overcome. Whilst the preceding chapters do not capture the authors' own accounts of the cultural, social, economic, and nutritional importance of the ocean to their communities, it is important to reflect on the lived experiences of women across the ocean space from academia to campaigning.

Whilst the challenges of exclusion through marginalization and underrepresentation are not unique to the natural and social sciences of the ocean, we felt it was necessary to address these experiences through this short editors' note. We collected accounts of the authors' lived experiences based on gender or other aspects of identity that have impacted their education, work, career choices, and professional development. Anecdotes abound, from gender inequity through dress codes and distribution of work, to hostile experiences ranging from belittling comments to sexually motivated crime. For those who can relate to these experiences, we hope they find comfort and feel empowered by the fact that they are not alone. For those to whom this comes as a surprise, and those who are interested to know more about the context of these incidents in marine science and society more generally, we encourage you to read our chapters on disparities and gender (Chaps. 29 and 30).

Researcher in the Arctic. *Credit* Esther Horvath

One of our authors eloquently described the professional landscape women operate in as one which requires them having *"to navigate the intentions of those we network with."* This landscape can include many obstacles, such as ulterior motives, gender-based exclusion, and explicit sexual harassment. In a field with such closely connected disciplines, such obstacles can have lasting impacts on women's experiences in the field. One author described being distressed by the prospect of another encounter with someone who had sexually harassed her whilst networking. Others reported challenges associated with power differentials, with one woman describing the challenge that she and other younger female colleagues had of navigating inappropriate advances by a senior male government official who was also the client responsible for signing off on their project. Another described an environment where a male manager with power over hiring and firing, contracts, and workloads *"insisted on holding hands or kissing some of the female employees,"* and would penalize those who did not comply. In another case, one author who ultimately reported inappropriate conduct and harassment found that her organization supported her male colleague, believing that she *"made it up to try to 'destroy him'"*. Intersectional discrimination was also reported. For instance, one author noted that being an older, unmarried woman without children and working in a field requiring physically demanding work had led to negative interactions with male colleagues, who had criticized her for not conforming to their expectations. Another author wrote that her age, sex, race, and pigmentation *"are all layers of my identity. When one person discriminates against me for one or several of these aspects, I just feel rejected as a person in one block"*.

Many of the authors reported experiences where their work had been attributed to—or even given to—a male colleague, or where they were mistaken as the assistant rather than the principal investigator. Some of the authors described instances where they were not viewed as authoritative or an expert on their subject. In one extreme case, an author was asked three times by a male politician whether she had written a report on which she was indicated as the author. In another, the author's campaign was given to a male employee with less experience, who was asked to be the face of her campaign despite her already having developed and led the campaign successfully. She was also told that her "*non-Western name was too complicated to include on media releases"*. Another author was introduced as leader on a project to a new partner, who immediately asked her boss whether, as a young woman, she was able to do this work. Yet another author discovered that a high-impact report that she and her female colleague had written had her male colleague's name placed as first author, despite his limited involvement.

Even when not facing explicit discrimination, fieldwork equipment is often not designed for women, which can at best make it difficult to work effectively and, at worst, can make daily activities dangerous. One author noted that essential equipment was only available in men's sizes from approved manufacturer catalogues: *"Small is way too big. It makes it hard to manoeuvre and be as safe and adept as people working with correctly sized gear"*.

These are non-exhaustive examples that illustrate the types of challenges faced by the authors in their respective fields, but are by no means unique to the authors. Occurrences at the lower end of the serious scale, such as poorly fitting workwear, are often overlooked or of little concern to workplaces and institutions, and as such remain unaddressed. Where reporting of experiences is an option and encouraged, it can still pose significant risks—both perceived and actual—to the individual who reports, in terms of their career, workplace relationships, and mental well-being. This means that both visible and invisible barriers exist to a safe, productive, and rewarding career for women when working on, studying, or protecting the ocean and those who depend upon it.

Finally, it is worth recognizing the strength and resilience of all those who contributed to this book. In reviewing the authors´ lived experiences, it is evident that these challenges continue to be common for women in the ocean space. It is upon reflection that we realize what we have had to overcome to get to where we are; despite these challenges, we have become accomplished experts in our field. At the same time, there are countless stories of women who have had to give up their careers or leave their passion projects because of the challenges they faced, not due to any lack of passion or relentless determination for the ocean, but because the cost for these women to continue was too high. This is to the detriment of ocean science and conservation. Not only is lack of representation and inclusion in the ocean space morally unacceptable, but exclusion also stifles contributions from underrepresented individuals, diminishing our collective potential to innovate and advance ocean science, sustainability, and conservation. To truly maximize our individual potential and accelerate ocean solutions, we must work to end the barriers faced by women and marginalized people.

Lauren Weatherdon speaking at the Women4Oceans event in London on the barriers that women face in the ocean space. *Credit* Angela Martin

Ways Forward

Strengthening representation of diverse experiences. By sharing these stories we can break down barriers. Whether directly, anonymously or through platforms like Women4Oceans, there is strength in sharing experiences. Articulating the challenges and obstacles we face in pursuing our careers empowers ourselves and others. Knowing that there are others who share our experiences, we diffuse some of our fears and guilt, and in some cases take away power from the abusers. For example, it may be that a person in power is acting inappropriately towards multiple people, and not just you. Once you know this, you are in a better position to protect yourself. It can be reassuring knowing there are others and that you are not to blame for the behaviour of that person. In this way we tilt the power dynamic. Below we list some suggestions for things you can do as an individual, followed by actions that employers and institutions can take.

As an individual, you can:

1. Be observant and mindful of others. You cannot know everyone's personal circumstance, but you can observe the way people are treated.
2. Be open to listening to the experiences of others. You may find solidarity.
3. Speak up for others when they cannot speak up for themselves.
4. Lift those around you. If you find a colleague is not getting recognition, for example if they are frequently ignored in a meeting, speak up and draw attention to them and their ideas.
5. Offer your support, such as by mentoring those junior to you, or those just joining your place of work/study.
6. Where possible, call out uncomfortable situations, either directly to the person creating it, their superior, or to a trusted colleague.
7. Keep a journal of experiences. Record time and dates of instances. If these challenges, or inappropriate behaviours happen over email or social media, then keep the records.

Specific to preventing sexual harassment and assault in professional spaces. Ocean sector employers and educational institutions can take steps to create safe and inclusive work or study environments for all by incorporating the measures listed below into organizational policies:

8. Enact a zero-tolerance policy for sexual harassment and assault.
9. Set and enforce consequences of sexual harassment and assault including termination of the perpetrator´s contract and an institutional investigation.
10. Ensure that all participants in the workplace are informed of the rules and the consequences of breaking them. Rules must be available both on site and online.
11. Establish adequate reporting channels: If no other institutional reporting channels are available during field courses and fieldwork settings, two members in authority positions should be designated to receive complaints.
12. Set high communication standards, including daily or regular check-ins when possible.

13. Build a community agreement: Invite staff, students and participants to contribute to a community agreement, including setting shared norms and rules for the group.
14. Create a position for a confidant. A confidant is someone who provides guidance and support for employees or students who struggle with or have complaints about the behaviours of others. This does not have to be limited to inappropriate behaviour relating to sex.

Although an aim of *The Ocean and Us* is to begin to address the exclusion of women and their narratives on the importance of the ocean, it also lacks diversity in other respects. In the same way that we would not want our experiences told by others, we are not in a position to tell theirs—so their stories are not in this book. We encourage you to think critically about the views you may readily receive through the media you consume and high-level events, given the context of all you have learned in this book. We further encourage readers to continue to seek out diverse perspectives on the ocean, its importance, and solutions to the threats it faces. Our chapters provide further reading suggestions but beyond these, there is a world of information and perspectives for you to explore.

Further Reading

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Better Leadership, Better World: Women Leading for the Global Goals https://www.unwomen.org/en/digital-library/multimedia/2020/2/infographic-visualizing-the-data-womens-representation

Farah Obaidullah I have been passionate about the ocean since as far back as I can remember. From picking up litter on the beach to exploring life in the shore break, my destiny to work for the ocean was sealed at a young age. I completed both my undergraduate and masters degrees from Imperial College in London. After four years of working as an environmental consultant, I redirected my career towards the ocean. I have spent the last 18 years campaigning for healthy oceans. My work has allowed me to travel the world, observing the beauty of the ocean and witnessing some of the most egregious practises happening at sea. I have worked on a whole range of ocean issues. Amongst others, I have executed campaigns to end destructive fishing, worked with affected communities, lobbied for ocean protection and exposed fish crimes, including slavery and labour abuse at sea. I am currently campaigning to secure a moratorium on deep-sea mining. Deep-sea mining is an emerging threat that we know will cause irreversible damage to the ocean. Unlike other destructive practises we can still prevent deep-sea mining from going ahead. I am biracial, bicultural, and consider myself a citizen of the world. I strongly believe that by embracing our human diversity and rediscovering our place in the natural world we can turn the tide for our ocean planet.

Lauren V. Weatherdon UN Environment Programme World, Conservation Monitoring Centre (UNEP-WCMC). Like many growing up in coastal British Columbia, I have always shared a passion for the coastal flora and fauna that characterize daily living and outdoor adventures. In later years, I completed a BA in Honours English Literature, one year towards a BA in Geography, and an MSc in Resource Management and Environmental Studies from the University of British Columbia. This interdisciplinary background has allowed me to experience nature in different ways, from literary explorations of how Spenser and Milton perceived nature in the 1500s and 1600s, to understanding how effective management of the ocean can improve ecological, social and cultural outcomes for society. These experiences have highlighted to me just how central nature is to individual and collective well-being for communities around the world, and the importance of conserving nature not only for its intrinsic value, but also for our survival. Since 2014, I have had the opportunity to work with UN agencies, governments, companies, and non-governmental partners in more than 20 countries around the world, with the shared aim to sustainably manage and conserve nature for people and planet.

Part VIII
Inspiring Voices

Chapter 32
Inspiring Voices: Inka Cresswell, Jamila Janna, Merrisa Naidoo, Louisa Ponnampalam, Vatosoa Rakotondrazafy, Jo Ruxton MBE, Marilyn Slett, Patima Tungpuchayakul

Farah Obaidullah and Zoé Winck

The Women4Oceans network around the world

The following profiles reflect some of the diversity of women around the world finding inspiring ways to communicate about the ocean and contribute to ocean health. From film-making to community organizing and coming up for those that depend on the ocean for their livelihoods, each one of us has something to contribute.

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Inka Cresswell—Giving A Voice to Our Oceans

United Kingdom

What keeps you going	A piece of advice	A quote	An inspiration
The fact that we have to	You don’t need the world’s best equipment: just a strong, captivating story	The sea, once it casts its spell, holds one in its net of wonder forever – Jacques Cousteau	Andrea Crostas’ work and ability to integrate film-making into real conservation action

I believe that film and photography are some of our most powerful tools in the fight to conserve our oceans. Film is an incredibly effective way of communicating ocean conservation messages as it allows us to connect with the audience through emotion as well as logic. It is this emotional connection to a species or an ecosystem that I feel is most effective in driving real conservation action. I specialize in underwater wildlife documentaries working as a self-shooting producer/director or presenter on smaller-scale projects and as a researcher on larger landmark series/films. This journey as a film-maker has led me to some of the most incredible underwater encounters. From documenting hammerhead tagging procedures in remote parts of the Pacific Ocean, to filming a group of grandmothers who have created their own sea snake ID citizen science team on the stunning reefs off New Caledonia. I have come eye to eye with great white sharks on countless occasions and even been bumped by curious blue sharks while working as a camera operator off my local coast here in the UK. I have listened to the stories from the fishermen who have become fish sanctuary rangers, assisting in the rebuilding of coral reef scapes. As a researcher in the wildlife film-making industry, I work with an incredible team made up of leading producers and directors, fantastic scientists, award-winning camera operators and pioneering divers. I work with scientists around the world, breaking down their research to craft a story in a way that will both educate and entertain an audience. I love this role as it allows me to indulge in endless amounts of scientific journals and discuss marine topics with world-leading experts. My job is to find stories; stories that don't just educate and inspire but most importantly captivate our audience.

My most recent film *'MY 25: The Ocean Between Us'* was a personal authored film exploring how our oceans have changed in just my lifetime, featuring shifting baselines and scientists from around the world who are working to conserve their coastlines. Most importantly, I have been able to use my experiences and platform to engage and inspire a new generation of ocean conservationists. As the director, I decided to feature local scientists/conservationists in each location creating a platform to showcase diversity in marine science. As a mixed-race woman, this is something I have always felt passionately about as I feel there has often been a lack of representation in STEM industries. It was a great opportunity to be able to showcase the variety of people from different backgrounds, ethnicities and professions coming together to protect our oceans. Since its release, this short film has been featured in film festivals globally, and I was especially proud to find out that it made the official selection at Wildscreen Film Festival and was a finalist at the 'World Wildlife Day film showcase' hosted by Jackson Wild, IUCN and CITES.

As a wildlife film-maker, my goal is to create films that will educate and inspire, but one of the greatest issues I face is ensuring my audience is left feeling hopeful and motivated. Often the focus of my work is an ocean conservation issue I want to highlight. Balancing these often hard-hitting conservation issues with hope is a difficult task, but it is no reason to shy away from difficult topics. One of the things I enjoy most about my work is being able to showcase the scientists who dedicate their lives to our oceans, their raw passion and determination are infectious, and I always love being able to capture that enthusiasm on the screen so others can share in their passion and gain a greater understanding and respect for the work they do.

About Inka Cresswell

From the first time she peered into a Rockpool on her local beach, Inka has been completely captivated by our oceans. Like many, it was the beauty that lies beneath the surface that first captured her curiosity. As she began learning about different marine ecosystems, that initial curiosity developed into a passion for marine biology. By the age of 6, she had already decided she was going to be a marine biologist. She never imagined that by the time she graduated from the university, she would find herself working to save the last of a species and documenting the end of an era. It was this desperate need to do something to save these ecosystems that led her into a career shift into wildlife film-making and science communication. She has a B.Sc. degree in marine biology and an M.A. in wildlife film-making. Her work has been featured on the BBC, dive brands and conservation organizations internationally. Inka also works as a social influencer in the diving industry, giving public talks on ocean conservation, conservation film-making and marine topics to inspire more girls to become involved in the wildlife film-making and STEM industries.

Jamila Janna—A Journey into Marine Conservation

South Africa

A key fact in your field	What keeps you going	Proudest achievement	Advice
More than 50% of our oxygen is derived from the ocean	My nieces and the next generations yet to inherit this planet	Making a conservation documentary	Remember the small things

My interest in the ocean was initially sparked by nature TV shows—no, not Sir David Attenborough, but shows that aired in New Zealand and Australia that we watched on satellite. I applied and was accepted at the University of KwaZulu-Natal to study marine biology. I fell in love with the subject but knew that my lack of practical experience in the field as a black female could be a career inhibitor. I voyaged across the vast expanse of Google Search on a quest to find organizations that I could volunteer or work with to gain experience. To my surprise, in 2018 I was accepted into the WILDOCEANS Ocean Steward programme which aims to expose students to offshore marine research. Through that programme, Youth for Marine Protected Areas (Y4MPAs) was created, and I became a spokesperson for the group. As I write this, I am on a journey of rediscovery. I ask myself, who am I and how does that serve my interests for the environment? Over the months, my fight has shifted to include a wide range of topics other than Marine Protected Areas, which include intersectionality in marine conservation, social justice in environmentalism and inclusion and leadership of BIPOC in conservation efforts.

During my time as a spokesperson, I have represented the voices of South African youth at several climate justice protests, by hosting and facilitating youth workshops, through written letters addressed to government, by collaborating with other youth networks and at local and international conferences, congresses and symposiums, for example the Convention on Biological Diversity, N.E.W.F Congress and The Conservation Symposium. If I were represented as a bucket and my growth as a scientist as droplets of water filling the bucket, then I have accumulated enough water to quench the thirst of one person—and that is it. I have learnt a great deal which has shifted my way of thinking and the 'what' I advocate for. While that is progress and growth and I'm grateful for it, I still have so much to learn, and it is both the frustrations and precious moments (also my lovely nieces) that keep me motivated to fight for the ocean and people. I need our oceans more than they need me, but its services are mine to enjoy only when I care for them with great love.

About Jamila Janna

Jamila Janna is a marine biologist pursuing her master's in zoology at the Stellenbosch University. She completed her undergraduate with honours at the University of KwaZulu-Natal. In 2018, she was accepted for the WILDOCEANS Ocean Steward programme. Later that year, Youth 4 MPAs (Y4MPAs) was initiated, and she was nominated as a spokesperson where she served from August 2018 to August 2020. In 2019, she was selected to participate in N.E.W. Filmmakers Underwater laboratories and become a N.E.W.F laboratories fellow. She also featured in the WILDOCEANS Our Oceans film. In 2020, she produced a short film titled Hluleka that highlights social injustices and promotes marine conservation and indigenous knowledge, respectively. To date, she has initiated a project called WILD Elements which aims to tackle key conservation issues and promote advances in Africa in conservation through honest conversations, art and science-telling.

Merrisa Naidoo—Protecting the World's Oceans

Youth4MPAs

South Africa

"She believed she could, and she did"—R.S. Grey

A key fact	A good idea	A piece of advice	An inspiration
Achieving the scientifically endorsed 30% ocean protection would ultimately deliver benefits that outweigh costs by 5-to-1	South Africa hosting the first African Youth Summit (Our Africa, Our Ocean, Our Future)	To my younger self… I wish I started as early as Greta Thunberg	Ruth Mthembu, a young, beautiful and vibrant African woman making waves in the ocean space

Today, I am proud to say that I represent one of the many integral youth voices that have been putting up the good fight to expand ocean protection in South Africa. In 2018, Y4MPAs or Youth4MPAs was conceived, and I was ready to sign up and become a part of a force of young people that stood to be reckoned with. Prior to October 2018, only 0.4% of the waters around South Africa were protected. It was on these grounds that the Youth for Marine Protected Areas was established and very soon became the driving force that called the South African government to take action on their promised 5% protection of South Africa's oceans. Today, Youth4MPAs continues to fight alongside the global youth in a bid to protect 30% of our world's oceans by 2030 (#30×30).

As I reflect on the journey of this movement, I recollect memories of my initial role. It was very much behind the scenes, making noise on social media, vastly different from the role I play in the movement today. It now involves having meaningful conversations with stakeholders to catalyse change, sitting in panels with global youth to network on achieving #30×30 and steering a committee of dedicated individuals to actively take decisions for the betterment and empowerment of our youth.

When I am called to answer the question, 'Who are the Youth4MPAs?', the following comes to mind: Youth for Marine Protected Areas comprise a group of marine enthusiasts from all walks of life, backgrounds and ethnicities with one common goal—to advocate for the proclamation and expansion of old and new MPAs in South Africa's oceans and stand in unity against any threats or harm that may come to our universal and life-giving mother 'the ocean'. The group is developing into an informed and passionate youth group within South Africa with over 256 members active across three provinces, incorporating over 40 different organizations. Their vision is simple; they believe that through the collective efforts of the youth to establish a network of connected Marine Protected Areas, a sustainable future can and will be achieved.

In the early days of the pandemic, I, together with the movement, took to the virtual stage to represent the movement at various international and national online summits and be a part of decision-making dialogues that advance our efforts in protecting everything under the 'blue blanket'.

The current status of the Y4MPAs movement can be perfectly encapsulated in the words of some of our members: 'our movement is still growing, but it is a group of like-minded people with nature and love in our hearts. We want to be part of the decision-making for the future environment we will inhabit. We strive for marine protection while addressing the social issues we face. Change is possible and there is hope for a better and healthier future. We are inspired to do better and play an active role in advocating for our oceans. After all, it is said that anything great that has ever been achieved has been achieved by youth.'

About Merrisa Naidoo

Merrisa Naidoo is an intern for WILDOCEANS South Africa which is a programme of the WILDTRUST. She is working under the Oceans Alive Blue Fund Project at WILDOCEANS. The Oceans Alive project aims to support a representative and effective regional network of connected Marine Protected Areas (MPAs). Merrisa submitted her M.Sc. in a collaboration project with the University of KwaZulu-Natal and the Knysna Basin Project, where she spent 2 years of her studies working on a first-ever assessment of microplastic pollution in the Knysna Estuary and its occurrence in juvenile fish and syngnathids (such as pipefish which are relatives of the endangered Knysna seahorse). Merrisa's key goal is to actively contribute to marine conservation in South Africa, and one of her major accomplishments is having been selected as WILDOCEANS' Ocean Steward in 2016 which has served as a stepping stone in the broader scope of marine science, supporting her selection ahead of 800 applicants worldwide to participate on the training expedition, SoNoAT 2019 on board the German RV. Polarstern (PS120). Apart from academia, Merrisa has also developed a key interest in awareness and education around her field and became the spokesperson of the dynamic Youth for Marine Protected Areas (Youth4MPAs) movement, which was represented at the UN Climate Dialogues on 3 December 2020.

Louisa Ponnampalam—Discovering and Protecting Marine Mammals

The MareCet Research Organization

Malaysia

An inspiration	A recognition	A good idea	A piece of advice
The late Dr Kanjana Adulyanukosol, who showed me what a good scientist and conservation leader should be	Pew Fellowship in Marine Conservation (2014)	MareCet's annual newsletter and our Whales-on-the-Wheels Mobile Marine Education Truck Programme	When entering the conservation field, don't limit yourself to the study of biology or ecology

Marine mammals are sentinels for the health of our seas and oceans. Our goals are to raise the profile of marine mammals in Malaysia and to work towards getting their habitats protected. By protecting their habitats, we protect our own lives and future. The efforts of MareCet consist of field research, e.g. spending time at sea collecting visual and acoustic data on cetaceans, looking through photographs of dolphin dorsal fins, listening through audio files and writing up our results for publication. Our findings are further converted into educational materials for school children and the general public. We also run social media awareness campaigns about marine mammals and share our findings to the decision-makers so as to contribute the results to national conservation planning documents. Through our research, we are identifying the threats and conservation needs of the species we work with. Our observations of dolphins with skin diseases and emaciation, for instance, tell us that their habitat is in peril. We are also working towards understanding the impacts of underwater noises on Indo-Pacific humpback dolphin vocalizations and determining areas of importance for the life cycles of the animals.

The core team at MareCet is composed almost entirely of young Malaysian women, women who are going on to become our next generation of conservationists and lead with heart and passion. We are working tirelessly to engage with our decision-makers to lobby for the protection of our field sites, all of which are now internationally recognized as Important Marine Mammal Areas (IMMAs) and to see to fruition the establishment of a sanctuary for endangered dugongs in Peninsular Malaysia.

About Louisa Ponnampalam

Whales and dolphins are charismatic animals that tend to earn a special place in the hearts of many. As a little girl growing up in Malaysia, Louisa dreamed of becoming a dolphin scientist and a conservationist but found it rather difficult to find information on dolphins in Malaysia. She went abroad to complete her tertiary education in marine science and dolphin ecology, returning to her homeland after nearly a decade to begin her quest of conducting research on dolphins. She quickly found out that the awareness towards marine mammals in Malaysia and their appreciation was low. In response to this, she co-founded the MareCet Research Organization in 2012 to conduct much needed applied scientific research on cetaceans (the collective term for whales, dolphins and porpoises) and dugongs. The findings are used to conduct marine education programmes and lobby the government to take more action to protect marine mammal habitats. MareCet was also founded to be a platform for growing local Malaysian research and conservation talent, to make available to others the dream of becoming a marine mammal conservationist.

Vatosoa Rakotondrazafy—Empowering Small-Scale Fishers

MIHARI Network

Madagascar

A misconception	A piece of advice	A good idea	A recognition
Fishing is not only a man's world. Women play a critical role in it and in sustainably managing coastal and marine resources	Do not be afraid to go beyond your comfort zone	The Fisherwomen Leadership Program. It elevates marginalized women's voices in community-led marine conservation nationally	Whitley Award (2019)

The reasons behind the collapse of healthy marine ecosystems are complex. In low-income countries around the world, millions of small-scale fishers rely on the ocean for food and income. They are witnessing first-hand the disappearance of once common fish. In areas where fish populations are already at risk of being overfished, additional fishing pressure from large-scale vessels can have devastating impacts for those whose lives are intimately linked to the ocean. The MIHARI Network was set up in 2012, and it is Madagascar's national network for Locally Managed Marine Areas (LMMAs). MIHARI is an acronym for *MItantana HArena Ranomasina avy eny Ifotony*, which translates as 'marine resource management at the local level'. MIHARI organizes learning exchanges and regular forums at regional and national levels, providing invaluable opportunities for those involved in sustainable management of marine areas to discuss the challenges they face and develop collaborative solutions.

MIHARI advocates for the rights of small-scale fishers in Madagascar. These communities face great hardship as they are located in isolated and dispersed areas, facing limited access to basic amenities, making them among the most vulnerable populations in the world. Despite their lack of opportunities, these communities are working hard to gain knowledge of how to best manage and use their marine and coastal resources. We encourage members to share best fisheries management practices among communities throughout Madagascar. MIHARI works with LMMA members and NGO partners, to ensure that the voices of small-scale fishers are heard and their rights considered, at national level.

During the six years that I have led MIHARI, the network has continued to develop and grow and is now made up of more than 200 community associations throughout Madagascar's coastal zones and 25 NGO partners. One of our biggest successes has been the drafting of a list of priorities for small-scale fishers across Madagascar, including the establishment of a series of designated areas reserved for small-scale fishers, securing their access to fisheries resources. These requests were granted in July 2018. MIHARI's work continues to focus on bringing the rights of Madagascar's small-scale fishers to the fore and ensuring they are involved in all discussions around the use of Madagascar's oceans. In order to address disagreements between industrial and small-scale fishers, I helped to set up formal discussions through workshops. As a result, the communication between the two groups has greatly improved, and they are working on plans to better collaborate going forward.

Being an ambassador for small-scale fishers is a privilege. I continue to learn from their experiences and am inspired by their determination and hope. The MIHARI Network places the future of Madagascar's small-scale fishers in safe hands.

About Vatosoa Rakotondrazafy

Throughout my early life, I fostered a sense of great empathy for the marginalized and vulnerable people I saw around me, those who live in poverty and those who struggle to find sufficient food to eat. I felt motivated to defend their rights and help them to improve their daily lives. I studied geography and took a course on ocean governance, which led me to undertake a year of research on strategies to improve the governance of Madagascar's fisheries with the United Nations in New York and the University of British Columbia. From this research, I learned how important it is to empower coastal communities to manage their country's marine resources. For six years, I led Madagascar's Locally Managed Marine Areas Network, called MIHARI. In 2019, I received the Whitley Award, which highlights the work of extraordinary conservationists leading work in their home countries to protect the natural world and its wildlife. I received the award in recognition of my role as a community ambassador and an advocate for the small-scale fishers of Madagascar. Today, I am the president of the board of MIHARI, and I have joined a think tank called INDRI, which mobilizes the collective brainpower of all stakeholders nationally to restore Madagascar's marine ecosystem and re-green the island.

Jo Ruxton MBE—Founder Ocean Generation

Plastic in the Ocean

United Kingdom

A quote	An inspiration	A misconception	A good idea
"We need to respect and take care of the oceans as if our lives depend on it. Because they do." Dr. Sylvia Earle	Sir David Attenborough, his never-ending enthusiasm and positivity about wildlife and the future of our planet	That there are continent-sized floating islands of plastic in the centre of the ocean—the truth is far more insidious	Leaving a staff job at the BBC to fund and produce my own environmental documentary (also the hardest thing I have ever done)

While making my own environmental film, ‘A Plastic Ocean’, I knew that if I wanted to bring an audience to an important issue, the film had to end with hope. I chose the topic of plastic in the ocean not only because it can be addressed easily by all of us but also because the reason we are in this mess is simple. In the mid-1950s, we were told that plastic was ‘disposable’, and for some unfathomable reason, we never questioned it. Plastic is a remarkable, versatile, cheap material that was designed to defy nature. It was designed not to break down but to last forever and yet here we are making single-use items out of it and throwing them ‘away’ when we are finished with them. When the truth of that simple fact dawns on us, it is usually enough to make us stop and think about our strange addiction to ‘use-once-and-throw-away’ items.

From the very beginning of my work in this field, I began to learn just how much misinformation there is online, one of many being stories about the so-called Great Pacific Garbage Patch—an area in the North Pacific Ocean described to be a giant continent-sized island of plastic, 10 m deep and ‘3 times the size of Spain’—among other comparisons. The first thing I did was to find a berth on a research vessel that was heading out there—1500 miles west of San Francisco, to the very centre of this fabled phenomenon. At the centre, I learned the truth behind the rumours. There is no floating island of plastic, and the sea looks as blue and beautiful as it ever did but what is far more insidious is the amount of microplastic particles, that are all but invisible, at the surface. Plastic leaving our shores is estimated to take up to 20 years to move to the ocean centre, once the dominant circular ocean currents pick it up. Salt water, wave action and sunshine all contribute to making each plastic item brittle. The more brittle they become the more they start to break up, eventually fragmenting into smaller and smaller pieces. The problem then is that they become plankton sized, and these are what is really accumulating in the ocean centres.

Plastics of this size are entering the marine food chain at the lowest level, carrying harmful chemicals as they go. We counted as many as 26 plastic fragments to each tiny planktonic creature on that journey in August 2009. With the equivalent of one truck of plastic waste entering the ocean every minute, I can only imagine how much the situation has intensified since our journey that summer. Although large floating plastic items can be pulled out of the ocean, removing it entirely would not be possible. Much of the plastic (an estimated 90%) eventually sinks to the seafloor and that includes the tiny fragments, once there they are mixed into the sediment. Our only option is to stop plastic reaching the ocean in the first place. That is what we are concentrating on at Plastic Oceans UK, through our evidence-based education and awareness programmes.

Another misconception is how long plastic will take to break down/disappear in the ocean. One number often quoted is 450 years for a plastic bottle, and there are plenty more 'statistics' out there on this but plastic was only invented 160 years ago so they are meaningless. And it is not just that, as far as we know, plastic only fragments into ever-smaller pieces and that doesn't stop with microplastics. The new studies being published on nanoplastics that we are breathing in tell, us that this process continues. Plastic does not disappear. It has been found in air samples over the ocean as well as over the land and nanoplastics coming from car tyres and brake-wear particles are now a further cause for concern.[1]

Plastic is so much a part of our lives and for many good reasons—especially in medicine—but it is time to address the things we *can* change and work together to keep our oceans safe for the future health of all.

About Jo Ruxton

Jo Ruxton is a passionate campaigner for the oceans: she started the first marine programme for WWF in Hong Kong by being a key advocate for the establishment of the first marine parks there. With a background in marine conservation, she was a lead member of the BBC's diving team while producing and directing underwater sequences since the first days of filming on Blue Planet in 1997. While she thoroughly enjoyed working in the first Blue Planet series, she became frustrated with the fact that the ocean was portrayed as pristine and full of amazing biodiversity, despite the fact that overfishing, pollution, acidification and coastal development were out of control. After her efforts to include more conservation messages were undermined, she left to work independently. When she started to hear about the problem of plastic waste in the oceans, she produced the documentary feature, *A Plastic Ocean*, (Netflix), a multi-award-winning film that was released in 70 countries. Jo co-founded Plastic Oceans, a registered UK charity in 2009 to continue the legacy of the film through evidence-based programmes in education, awareness, science and sustainability. Plastic Oceans rebranded to become Ocean Generation in 2021 with a bigger focus on other ocean issues and with a goal to restore a sustainable relationship between humanity and the ocean.

Currently, Jo is just beginning to work in the production of her next film and is busy in fundraising. She was awarded an MBE in the 2022 New Year's Honours in recognition of her services to marine conservation.

[1] Ref. Evangellou et al. 2020 Nature Communications 11 3381.

Marilyn Slett—Protecting the Ocean for Humankind

Heiltsuk Nation

A quote	Something that keeps you going	A misconception	A piece of advice
My late uncle Cyril Carpenter would say "when the tide goes out … the table is set" making reference to the ocean being our breadbasket. This saying inspires me every time I say it	Self care. Connection to family, friends, community and to our homelands. Nurturing our spirit through ceremony, honouring ourselves and spending time in our beautiful lands always helps to restore my sense of balance	That coastal first nations are anti-development. Our model supports the re-emergence of a conservation-based economy while taking into account the biodiversity of the Great Bear Rainforest	Take the time to ground yourself in your own leadership. It is normal to have some self-doubt, but don't let it overtake you, turn it around and face it. You will grow into the leader you are meant to be

As Heiltsuk citizens, we belong to our homelands, and since time immemorial, our Háiłzaqv ancestors have lived to protect our land, sea, resources, our history, culture and language, as they collectively protect our Háiłzaqv way of life. As modern-day Háiłzaqv, we, each, have a deep-rooted responsibility to protect and steward our territory for the generations that will follow us. Heiltsuk territory, known as the central coast of British Columbia, includes 35,553 km^2 (13,727 square miles) of land and sea, and our nation has almost 2500 members. As coastal people, we hold deep interconnections of mutual respect with the ocean, and as Indigenous people, we are often the first to be impacted by colonial practices and industry. Our community has been working hard to do our part in building a conservation-based economy. For more than 40 years, our community has fought to protect our territory from oil tankers and the threat of oil spills, dating back to the 1977 West Coast Oil Ports Hearings. I'd like to share two examples of our successes.

First is defeating the Northern Gateway Pipeline and Passing the Oil Tanker Moratorium Act. In 2016, after more than four years of community activism and lobbying against the pipeline—including emotional participation in the National Energy Board hearing—we won a lawsuit before the Canadian Federal Court of Appeal. The court quashed the approval of the Enbridge Northern Gateway pipeline which would have brought hundreds of oil tankers to BC's coastline every year. In 2019, we successfully lobbied the Canadian government to pass Bill C-48, the *Oil Tanker Moratorium Act* (OTMA). This Act prohibits oil tankers from carrying crude and persistent oils as cargo and from stopping, loading, or unloading at ports on the central coast of British Columbia, including in Heiltsuk territory. Building on our earlier success, this was a multi-year effort that required perseverance and a deep commitment from our community. Today, the OTMA is good public policy. It significantly reduces the risk of a major oil spill in our ecologically sensitive coastal waters, and we will continue to work with the government to ensure it remains intact.

Second is creating an Indigenous Marine Response Centre (IMRC). Despite our best efforts to reduce the risk of oil spills in our territory, we are not immune to human error and the dangers of marine traffic. On 13 October 2016, an American-owned tug and articulated barge, the *Nathan E. Stewart* (NES), ran aground in Heiltsuk territory after the watchperson fell asleep. We felt helpless as we watched a late and ineffective coast guard response attempt to clean up 110,000 L of diesel fuel, lubricants, heavy oils and other pollutants. The contaminants had spilled into Gale Pass, an important Heiltsuk food harvesting village and cultural site. The spill devastated our commercial clam fishery and harmed our ability to harvest the traditional foods that have sustained our people for millennia. After this traumatic and destructive experience, we decided we didn't want to be in such a position ever again. Our joint leadership (traditional chiefs and elected council) developed a vision for an Indigenous Marine Response Centre (IMRC), which would be based on the best spill response practices from around the world and would draw upon the traditional and local knowledge of our seafaring community. In spring 2021, our joint leadership signed a memorandum of understanding with the Canadian Coast Guard and Transport Canada to develop a Heiltsuk Marine Emergency Response Team. This community-based response team will conduct first strike response efforts in the event of an oil spill and will play an important role in collaborative incident response. This team is an important step to improving our community's capacity and paves the way for further discussions on how to realize our vision of an Indigenous Marine Response Centre to better protect our lands and waters and to secure long-term sustainable employment for our nation.

About Marilyn Slett

K̓áwáziɫ Marilyn Slett is a citizen of the Heiltsuk Nation based in Bella Bella, on the central Pacific coast of Canada. Her Háiɫzaqv (Heiltsuk) traditional names are Ǧáǧvi and K̓áwáziɫ, handed down over generations from her mother's side of the family. Her father Randolph is their family historian. She is also a descendant of Captain Carpenter from her fathers' side of the family. Captain Carpenter was a renowned Háiɫzaqv carver, canoe and boat maker. During one of her many round trips to

Ottawa, she read the testimony of her uncles—Steve, Cyril and Fred Carpenter—from the West Coast Oil Ports hearings in 1977. Their fears and concerns at that time were just as relevant today, and their words strengthened her perseverance to represent the Nation's position against supertankers. K̇áwáziɫ Marilyn Slett is the elected chief councillor of the Heiltsuk Tribal Council, currently serving her fourth consecutive term. She is the president of Coastal First Nations/Great Bear Initiative and served as the co-chair of the Wild Salmon Advisory Council. During her time as the chief councillor, Marilyn has guided the Nation on many major endeavours focused on protecting Heiltsuk title and rights and Heiltsuk territory. As a daughter of the Heiltsuk Nation, she will never stop fighting to preserve their cultural and spiritual way of life and the coastal wildlife and ecosystems that they depend on. This is a mindset held by all Háiɫzaqv past, present and future, and it is one she hopes will be adopted by citizens around the world.

Patima Tungpuchayakul—Fighting Against Modern Slavery in the Fishing and Seafood Industries

Labour Protection Network Foundation (LPN)

Thailand

A key fact	An encounter	A nomination	A piece of advice
95% of migrant children in Thailand have no access to government services	An ordinary old man called Pu Yen (Grandpa Yen) who made a huge impact on Thai people	Nobel Peace Prize (2017)	We can create our own opportunity if we believe in it. There's always hope no matter what

In the seas of South East Asia, far away from the eyes of the consumer, tens of thousands of men work as slaves for Thailand's fishing companies. Decades of overfishing mean that vessels have to go far out to sea for their catch, often spending months at a time away from land. This is the perfect setting for human rights abuse. Thai, Burmese, Cambodian and Lao fishermen have suffered gross abuses of their rights, especially among the islands of the Indonesian archipelago. For this reason, we established the Seafarer Action Centre, with the goal of bringing assistance and solidarity to those enslaved on Thai fishing vessels.

The operation began with reports of Thai boats fishing in Indonesian waters with crews of forced labour on board. For years, we worked to raise awareness among the public and decision-makers of the plight of these forced and bonded labourers. Unfortunately, our efforts were met with little action. We knew we had to do something. So, after hearing about 128 survivors of forced labour aboard fishing boats in Indonesia, we decided to undertake our own operation by travelling to Indonesia to seek out enslaved and stranded fishers.

Our mission to Indonesia resulted in a mass rescue operation and provided momentum for reform. Some of our significant achievements include

- Discovery and rescue of 5000 fishing workers trapped in Benjina, Ambon and other Indonesian islands, through collaborative efforts by the Indonesian and Thai governments and international organizations, observed and reported by the mass media, from 2014 to 2017.
- An increase in awareness about modern slavery in the fishing industry among consumers and a rise in concern over conditions of labourers in seafood supply chains, placing pressure on businesses.
- Changes at the policy level on labour rights protection, leading to the updating of many of Thailand's labour laws. The government established Port-In Port-Out Centres for monitoring and surveillance of vessels entering and departing from Thai ports, to ensure they are legal and adhere to proper labour standards. This complements the efforts to promote traceability in the seafood supply chain to ensure that Thailand will be free from seafood products obtained through illegal and unsustainable fishing processes and exploitation.
- Workers in Indonesia received assistance to return home, some returning to families they have not seen for 24 years.
- Production of the documentary film 'Ghost Fleet' to expose the issue of slave labour to audiences of seafood consumers around the world. Through footage and personal stories from the rescue operation, 'Ghost Fleet' demonstrates the continuing prevalence of slavery in the modern world. In 2019, the movie screened at film festivals in multiple countries including the USA, Canada, the UK, the Netherlands, Egypt, Japan, Colombia and New Zealand.
- Integration of labour issues into the global conversation on marine conservation and illegal fishing, bringing together questions of forced labour and sustainability during World Oceans Day 2019.

- Raising the issues of human trafficking in the fishing industry, and belated assessment of the seafood supply chain, at the ASEAN level, to encourage collaboration at a regional and global scale.
- Amplifying the voices of seafood industry workers and forced labour survivors, allowing them space to share their ideas and needs.

The voices of fishers and of forced labour survivors are raised globally, to spread the lesson that these attacks on human dignity should never be allowed to happen again. When survivors' voices are clearly heard, the world will respond. They deserve our solidarity in their fight against abuse and discrimination, and we will never allow the needs of our fellow humans, or of our planet, to be overlooked. Thank you to the villagers in Indonesia and the survivors of slave labour, who helped and supported each other while waiting for the chance to return home. Thank you brothers and sisters from Thailand, Myanmar, Cambodia and Laos for your encouragement and for the information helping us to track down lost victims. And finally, thank you everyone for reading about my work. Through your choices, you are a part of our struggle to eliminate modern slavery in the fishing and seafood industries, to ensure the seafood you eat is not produced by slave labour.

About Patima Tungpuchayakul

Patima Tungpuchayakul is a Thai national and the co-founder of the Labour Protection Network Foundation (LPN). LPN is an organization working to tackle modern slavery in the fishing and seafood industries, both in Thailand and across the globe. Her interest in human rights began in 1996 after graduation from Mahasarakham University, when she realized that the owners of factories near her home, north of Bangkok, were abusing migrant workers, especially women and children. Since then, her mission has been to raise awareness around human rights abuse, rescue fishermen from slavery in the seafood sector and work with reformers to provide adequate protection for all migrant workers.

Farah Obaidullah I have been passionate about the ocean since as far back as I can remember. From picking up litter on the beach to exploring life in the shore break, my destiny to work for the ocean was sealed at a young age. I completed both my undergraduate and masters degrees from Imperial College in London. After four years of working as an environmental consultant, I redirected my career towards the ocean. I have spent the last 18 years campaigning for healthy oceans. My work has allowed me to travel the world, observing the beauty of the ocean and witnessing some of the most egregious practises happening at sea. I have worked on a whole range of ocean issues. Amongst others, I have executed campaigns to end destructive fishing, worked with affected communities, lobbied for ocean protection and exposed fish crimes, including slavery and labour abuse at sea. I am currently campaigning to secure a moratorium on deep-sea mining. Deep-sea mining is an emerging threat that we know will cause irreversible damage to the ocean. Unlike other destructive practises we can still prevent deep-sea mining from going ahead. I am biracial, bicultural, and consider myself a citizen of the world. I strongly believe that by embracing our human diversity and rediscovering our place in the natural world we can turn the tide for our ocean planet.

Zoé Winck is a freelance writer based in The Hague, The Netherlands. With a degree in Politics from the University of Sussex, they are passionate about sustainability transitions and local initiatives. Their writing focuses on amplifying marginalized voices.

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