30X30

IN HOT WATER: THE CLIMATE CRISIS AND THE URGENT NEED FOR OCEAN PROTECTION

GREENPEACE

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Flying fish in the Sargasso Sea
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Walrus on an ice floe in the Chukchi Sea
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FOREWORD

We are standing at a pivotal moment in history. A global movement unlike anything we've seen before is demanding governments take action to address the climate emergency. Young people, inspired by Swedish activist Greta Thunberg and many others, are at the forefront of a passionate, growing movement that is grounded in science. It is their future that is being shaped by the decisions being made now. It is their future that governments are toying with as they deliberate over vague promises and voluntary commitments.

The science could not be clearer: at most, we have 10 years to avoid crossing the 1.5°C heating threshold. The consequential increase in existential risks to nature and people is undeniable. The most recent report from 11,000 scientists across 153 countries said that without swift action, 'untold human suffering' is unavoidable.

The impacts, which we're still grappling to comprehend, will be widespread and far-reaching. Sea level rise will redraw the coastlines of many countries over the course of the coming century, with devastating research recently published in the academic journal Nature Communications roughly tripling the number of people estimated to be at risk. Nearly three quarters of the communities newly estimated to be vulnerable live in eight Asian countries, with the biggest chunk in China. More than 10% of the current populations of nations including Bangladesh, Vietnam, and many Small Island Developing States are among the most at risk, threatened by chronic coastal flooding or permanent inundation.

Sea level rise is just one of the major ocean impacts of human emissions of CO_2 into the atmosphere. The ocean is the beating blue heart of this planet—essential to each and every one of us.

Increasing levels of CO_2 are causing ocean heating, acidification and deoxygenation, leading to changes in oceanic circulation and chemistry, rising sea levels, increased storm intensity, and changes in the diversity and abundance of marine species.

Two recent and substantive reports—the IPCC's Special Report on the Ocean and Cryosphere and the IPBES Global Assessment Report on Biodiversity and Ecosystem Services—set out the complex interplay between ocean and climate. They explain not only the impacts of rising greenhouse gasses on the ocean, but how ocean and marine life carries out essential ecosystem functions which, among other things, provide food, sequester and store carbon, and generate oxygen.

This report draws on this research and much of the recent science. It sets out how, by protecting at least 30% of the ocean in a network of ocean sanctuaries, we can build resilience in ocean ecosystems so they can better withstand rapid changes, and help mitigate climate change by promoting carbon sequestration and storage.

Building a global network of ocean sanctuaries in both coastal waters and international waters will help buffer against both management and environmental uncertainty.

2020 is a crucial year for protecting our oceans. There is the opportunity for countries to agree to a new Global Ocean Treaty at the UN, and at the Convention on Biological Diversity nations must pledge to protect at least 30% of the oceans by 2030. There is also a climate summit where all countries must agree to increase their action to reduce the gases that cause climate change. Leaders have to implement effective ocean protection at a scale commensurate to the ecological threats, and commit to strengthening national climate plans and associated Nationally Determined Contributions (NDCs) in line with the 1.5°C limit.

The science is inescapable and the urgent need for action is undeniable. To avert reaching further looming ecological tipping points, governments must heed the calls of their citizens and act now.

jmorgan

By Jennifer Morgan, Executive Director of Greenpeace International

EINLEITUNG

> Of all risks, it is in relation to the environment that the world is most clearly sleepwalking into catastrophe." —World Economic Forum[1]

Im Mai 2019 veröffentlichte der Weltbiodiversitätsrat der Vereinten Nationen (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, IPBES) die umfassendste jemals durchgeführte Bewertung der weltweiten Artenvielfalt[2]. Die schockierenden Ergebnisse dieser globalen Bestandsaufnahme des Zustandes der Natur, der Ökosysteme und der Bedeutung der Natur für das menschliche Überleben stützen sich auf rund 15.000 wissenschaftliche und staatliche Quellen sowie indigenes Wissen. Der beschriebene Verlust in der Natur ist beispiellos, wobei das Ausmaß des Artensterbens derart vorangeschritten ist, dass eine Million Arten vom Aussterben bedroht sind. Viele davon innerhalb der kommenden Jahrzehnte. Das sind mehr Spezies als jemals zuvor in der Geschichte der Menschheit[3]. Zu den bedrohten Arten gehören fast 33 Prozent der riffbildenden Korallen und mehr als ein Drittel aller Meeressäugetiere.

Der Bericht zeigt, dass nicht nur die Ökosysteme an Land durch menschliche Aktivitäten stark beeinträchtigt werden. Bislang wurden auch zwei Drittel der Meeresumwelt, von den Küstengebieten bis zur Tiefsee, durch menschliches Wirken „stark verändert". Überfischung und zerstörerische Fangmethoden fordern ihren Tribut: Im Jahr 2015 wurden 33 Prozent der kommerziell genutzten Fischbestände in den Ozeanen auf nicht nachhaltigem Niveau befischt, weitere 60 Prozent wurden bis an ihre Grenzen ausgebeutet. Lediglich sieben Prozent wurden als „unterfischt" eingestuft[4]. Hinzu kommt, dass nach einigen Studien die illegale, nicht gemeldete und unregulierte Fischerei (IUU) schätzungsweise 15 bis 30 Prozent der weltweiten jährlichen Fangmengen ausmacht. Da weltweit mehr als 30 Millionen Menschen von kleinskaliger regionaler Fischerei abhängig sind, darf die Bedeutung dieser Zahl für die globale Ernährungssicherheit nicht unterbewertet werden.

Die grenzenlose Ausbeutung der natürlichen Ressourcen ist ein treibender Faktor für den Verlust der biologischen Vielfalt und für die Veränderung der Ökosysteme weltweit, aber sie ist nicht allein. Auch die Folgen der Klimakrise, die Versauerung der Ozeane, die Vermüllung und Verschmutzung sowie die Einwanderung invasiver Arten sind wichtige Faktoren und ihre Konsequenzen für die Meere sind enorm. So sank die Verbreitung von Seegraswiesen von 1970 bis 2000 um über zehn Prozent pro Jahrzehnt[5]. Ebenso hat sich die Riffbedeckung mit lebenden Korallen in den letzten 150 Jahren fast halbiert und in den letzten zwei bis drei Jahrzehnten weiter dramatisch verringert. Erhöhte Wassertemperaturen, regelrechte Hitzewellen in den Meeren und Versauerung – allesamt verbunden mit einem steigenden Kohlendioxidausstoß durch menschliche Aktivitäten – haben die Krise beschleunigt. Die Lebensgrundlagen von schätzungsweise 100 bis 300 Millionen Menschen sind durch den damit einhergehenden Küstenschutzverlust gefährdet. Darüber hinaus breiten sich „Todeszonen" aus – hypoxische Bereiche mit sehr niedrigem Sauerstoffgehalt, die durch landwirtschaftliche Überdüngung verursacht werden – und umfassen nun eine Gesamtfläche von mehr als 245.000 Quadratkilometer.

> The loss of species, ecosystems and genetic diversity is already a global and generational threat to human well-being. Protecting the invaluable contributions of nature to people will be the defining challenge of decades to come."
>
> —Sir Robert Watson,
> IPBES Chair

Der IPBES-Bericht unterstreicht die schwerwiegenden Veränderungen, die die Klimakrise für die Meeresumwelt mit sich bringt. Er prognostiziert einen Rückgang der Nettoprimärproduktion im Meer um drei bis zehn Prozent und damit einen Rückgang der Fischbiomasse um drei bis 25 Prozent bis zum Ende des Jahrhunderts. Veränderungen in der Struktur und Funktionsweise der marinen Nahrungsnetze bedingen Kaskadeneffekte auf die globalen Systeme der Erde wie die Regulierung des Klimas oder die Speicherung von Kohlenstoff. Einige dieser Änderungen können zu einer Verstärkung der Rückkopplungsschleifen führen, wodurch sich das Problem verschärft – hierzu gehört z. B. die Erhöhung der Freisetzung von CO_2 in die Atmosphäre durch eine erhöhte Bakterienaktivität im Ozean[6].

Die Veröffentlichung des Sonderberichtes des Weltklimarates (IPCC) vom September 2019 zum Ozean und der Kryosphäre hat unser wachsendes Verständnis für die

Gorgonian coral fan in the Great Australian Bight
© Richard Robinson / Greenpeace

komplexen und umfassenden Wechselwirkungen zwischen dem globalen Klima und den Ozeanen vertieft und die schwerwiegenden Auswirkungen der derzeitigen klimatischen Veränderungen auf das Leben im Meer und die Menschheit verblüffend deutlich gemacht[7]. Greenpeace zählt darauf, dass die Veröffentlichung eine koordinierte Reaktion auslöst, die sowohl die Klimakrise als auch den Schutz der Meeresökosysteme gleichzeitig angeht[8].

Seit der Unterzeichnung des Pariser Abkommens 2015 gibt es einen ermutigenden politischen Impuls der Integration von Meeresschutz und Maßnahmen gegen die Erderhitzung – eine solche Koordination ist unerlässlich wenn der Schutz der Meere im notwendigen Ausmaß gewährleistet sein soll. Eine Reihe anstehender internationaler politischer Treffen stellt eine entscheidende Gelegenheit dar, die eng verflochtenen Gefährdungen durch den Klimawandel und den Verlust der Artenvielfalt ehrgeizig anzugehen.

Der Weltklimarat hat deutlich gemacht, dass die globalen Emissionen von Treibhausgasen bis 2030 um etwa 45 Prozent gegenüber dem Niveau von 2010 und bis etwa 2050 auf null gesenkt werden müssen, um die globale Erwärmung auf 1,5 Grad Celsius zu begrenzen[9]. Dieses erfordert eine vollständige Transformation unserer Wirtschaft und Gesellschaft, hin zur Dekarbonisierung und zur Entwicklung einer Kreislaufwirtschaft[10]. Dazu gehören die Beendigung weiterer Erforschung und Gewinnung fossiler Energieträger, die Stromerzeugung aus erneuerbaren Energien, die Verbesserung der Energieeffizienz von Häusern, Fabriken und Büros, die Schaffung eines intelligenten Stromnetzes, die Abschaffung des Verbrennungsmotors, die Aufwertung des öffentlichen Verkehrs und die Umwandlung der Landwirtschaft in ein gesünderes und nachhaltigeres Ernährungs- und Landwirtschaftsmodell. Parallel zu diesen gesellschaftlichen Veränderungen müssen Naturlandschaften und Meereslandschaften erhalten und wiederhergestellt werden. Darüber hinaus müssen natürliche Kohlenstoffspeicher geschützt und ihre Entstehungsprozesse aufrechterhalten und verbessert werden.

Dieser Bericht verdeutlicht, warum mindestens 30 Prozent der Weltmeere geschützt werden müssen – um dem Leben im Meer eine Überlebenschance in einer ungewissen Zukunft zu geben und ihm zu erlauben, sich an die Erderhitzung, die Versauerung und den sinkenden Sauerstoffgehalt anzupassen. Außerdem wird die Widerstandsfähigkeit der Meeresökosysteme gegen die genannten Faktoren durch echte Schutzgebiete erhöht. Der Bericht zeigt auf, wie Netzwerke von Meeresschutzgebieten dazu beitragen, den gesamten Planeten gesund zu halten und die schlimmsten Auswirkungen der globalen Erwärmung einzudämmen: indem der „blaue Kohlenstoffspeicher“ geschützt wird.

An iceberg melting in Antarctica
© Steven Morgan / Greenpeace

INTRODUCTION

> **"Of all risks, it is in relation to the environment that the world is most clearly sleepwalking into catastrophe." —World Economic Forum[1]**

In May 2019 the United Nations' Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) published the most comprehensive assessment ever undertaken of the world's biodiversity.[2] The findings of this global synthesis of the state of nature, ecosystems and nature's contributions to people—which draws on about 15,000 scientific and government sources as well as Indigenous knowledge—are truly shocking. The decline in nature is unprecedented, with species extinction rates accelerating to the extent that one million species are threatened with extinction, many within decades. This is more than ever before in human history.[3] Among the threatened species are almost 33% of reef-forming corals and more than a third of all marine mammals.

The report demonstrates that it is not only terrestrial environments that are being lost and severely degraded by human activity. To date, two thirds of marine environments, from coastal areas to the deep sea, have been 'severely altered' by human actions. Overfishing and destructive fishing practices are taking their toll. In 2015, 33% of marine fish stocks were judged as being harvested at unsustainable levels, with a further 60% fully exploited. A mere 7% were considered 'underfished'. To make matters worse, according to some studies illegal, unreported or unregulated fishing (IUU) accounts for an estimated 15 to 30% of global annual catches.[4] With over 30 million people involved in small scale fisheries globally, the importance of these figures to global food security cannot be understated.

Exploitation is a major driver of biodiversity loss and ecosystem change globally, but it is not the only one. In the marine environment, changes in sea use, climate change, ocean acidification, pollution and invasive species are also major drivers—the effects of which are enormous. For example, the proliferation of seagrass meadows decreased by over 10% per decade from 1970-2000.[5] Similarly, live coral cover on reefs has nearly halved in the past 150 years and dramatically declined over the past two to three decades. Increased water temperature, marine heatwaves and ocean acidification —all linked to rising levels of carbon dioxide from human activities—has accelerated this crisis. The livelihoods of an estimated 100–300 million people are therefore at risk due to the associated loss of coastal protection.

Factory fishing in the English Channel
© Christian Åslund / Greenpeace

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> **—Sir Robert Watson, IPBES Chair**

Furthermore, 'dead zones'—hypoxic areas of low oxygen caused as a result of fertilizer run-off—are intensifying and now cover a total area greater than 245,000 km^2. The IPBES report underscores the severe changes being inflicted on the marine environment by climate change. It notes that there will be a 3–10% projected decrease in net ocean primary production by the end of the century, with an associated 3–25% projected decrease in fish biomass. Changes in the structure and functioning of marine food webs will have knock-on effects on the ability of the ocean to help keep the earth's systems functioning well, including climate regulation and carbon storage. Some of these changes may lead to amplifying feedback loops that exacerbate the problem, such as increasing the release of CO_2 into the atmosphere[6] through increased bacterial respiration in the ocean.

The September 2019 publication of the Intergovernmental Panel on Climate Change (IPCC) Special Report on the Ocean and Cryosphere has deepened our growing understanding of the complex and extensive interactions between the global climate and the ocean, and made startlingly evident the grave implications to both marine life and humanity of the changes that are underway.[7] Greenpeace hopes the publication of this report will galvanise a coordinated response that addresses both the climate crisis and the protection of ocean ecosystems simultaneously.[8]

Encouragingly, since the signing of the 2015 Paris Agreement, there is an increased political impetus to integrate oceans and climate work—a level of coordination that is essential if we are to deliver ocean protection on the scale required. A number of upcoming international political meetings constitute a crucial opportunity to ambitiously address the interconnected issues now jeopardising ocean health and human life on Earth, particularly climate change and biodiversity loss.

The IPCC has made clear that by 2030, global emissions must be cut by about 45% from 2010 levels, reaching 'net zero' by around 2050 to set us on the right track for limiting global warming to 1.5°C.[9] This will require a total transformation of our economy and society, towards decarbonisation and the development of a circular economy via a variety of means.[10] These include stopping further exploration for and extraction of fossil fuels, dramatically increasing our renewable power generation, improving the energy efficiency of homes, factories and offices and making them resilient to a changing climate, creating a smart electricity grid, phasing-out the internal combustion engine, improving public transport and transforming agriculture to a healthier and more sustainable food and farming model. In tandem to these societal changes, we need to conserve and restore natural landscapes and seascapes and, in doing so, protect and revitalise wildlife. Moreover, we need to ensure that natural stores of carbon are defended, and the processes by which they are created are maintained and enhanced.

This report makes the case as to why protecting at least 30% of the world's oceans is critical in giving marine life a chance to survive an uncertain future and adapt to climate change, ocean acidification and deoxygenation, whilst helping build the resilience of ocean ecosystems against these and other pressures. Furthermore, it explains how establishing ocean sanctuary networks helps keep the rest of the planet healthy and explores how this may reduce global warming's worst effects by protecting natural blue carbon stores and the processes by which they accumulate.

Fish in the Maldives
© Paul Hilton / Greenpeace

ERGEBNISSE

→ Jeder Mensch ist auf gesunde Ozeane mit reichhaltigen und intakten Ökosystemen mit ihren für uns alle überlebenswichtigen Eigenschaften angewiesen. Auch bei der Regulierung des Klimas sowie der Aufnahme und Speicherung von Kohlenstoff spielen die Ozeane eine wichtige Rolle.

→ Klimawandel und Artenverlust in den Meeren müssen aufgrund der Wechselbeziehung zwischen den natürlichen Lebensräumen und den Veränderungen beim Klima zusammen angegangen werden. Allerdings gibt es aktuell keinen international abgestimmten Fahrplan oder ein globales Gremium, um diesen Herausforderungen gerecht zu werden.

→ Die rasante Geschwindigkeit der sich verändernden chemischen Zusammensetzung der Ozeane wird weitreichende Folgen für die Meereslebewesen und -ökosysteme haben. Einige Arten werden in weniger betroffene oder nicht betroffene Gebiete auswandern, andere werden sich anpassen, wieder andere werden aussterben.

→ Unsere Abhängigkeit von der Verbrennung fossiler Energieträger und den daraus resultierenden Kohlendioxid (CO_2) – Emissionen hat zu Meereserwärmung, Meeresspiegelanstieg, Versauerung und Sauerstoffentzug geführt. Die Folgen dieser Auswirkungen sind rasant, großflächig und stören bereits weltweit die Ökosystemstruktur und ihre Funktionen – mit weitreichenden Auswirkungen auf die Artenvielfalt und schließlich auch für uns Menschen.

→ Um die menschengemachten CO_2-Einträge in die Ozeanen zu reduzieren und die Klimakrise zu mildern, müssen die Emissionen an Land drastisch gesenkt werden. Die Risiken sind bei einer globalen Erwärmung von 1,5°C deutlich geringer als bei 2°C.

→ Vollständig geschützte Meeresgebiete, in denen alle extraktiven Nutzungsformen untersagt sind, erhöhen die Widerstandskraft der Meere gegenüber den vielfältigen Belastungen, die durch Klimakrise, Versauerung und Sauerstoffmangel entstehen.

→ Die Einrichtung eines globalen Netzwerks von Meeresschutzgebieten, das eine Vielzahl von Lebensräumen umfasst, ist von entscheidender Bedeutung für den Schutz der natürlichen CO_2-Speicher im Meer („blauer Kohlenstoffspeicher").

→ 2020 muss sich die Welt auf einen globalen Ozeanvertrag und die Einrichtung eines Netzwerks von Hochseeschutzgebieten einigen, um unsere Meere zu retten und zerstörte Lebensräume wieder herzustellen.

→ Bei der 2020 stattfindenden nächsten Vertragsstaatenkonferenz (COP 15) der Biodiversitätskonvention (Übereinkommen über die biologische Vielfalt, CBD) müssen die Regierungen global verbindliche Ziele für den Schutz von mindestens 30 Prozent der Meere bis 2030 beschließen. Dazu muss ein Netzwerk von Schutzgebieten eingerichtet werden. Die verbleibenden 70 Prozent der Ozeane müssen nachhaltig bewirtschaftet werden.

→ Der Tiefseebergbau stellt eine Gefahr für die Artenvielfalt und die Lebensräume der Tiefsee dar, dazu gehört auch ihre Fähigkeit, Kohlenstoff zu speichern. Ein Verbot des Tiefseebergbaus ist unerlässlich, da er nicht so reguliert werden kann, dass Ökosysteme unbelastet blieben und ein wirksamer Schutz der Meeresumwelt gewährleistet wäre.

KEY FINDINGS

- Every human being on Earth depends on a healthy ocean with thriving marine ecosystems and the vital functions they provide within the Earth system, including their role in regulating the climate and the sequestration and storage of carbon.

- Climate change and loss of ocean biodiversity cannot be tackled separately because of the interlinkage of natural ecosystems and the climate, yet there is no multilateral plan, nor global body with the relevant capabilities to deal with these twin crises.

- The pace of change in basic ocean chemistry is likely to have far-ranging impacts on marine species and ecosystems. Some species will migrate to less affected or unaffected areas, some will adapt and others will be driven to extinction.

- Our continued reliance on burning fossil fuels and the resulting carbon dioxide (CO_2) emissions has led to ocean heating, sea level rise, ocean acidification and deoxygenation. The impacts of these changes are rapid and large-scale, already disrupting ecosystem structure and functions across the globe with far-reaching implications for both biodiversity and humankind.

- The only mechanism open to us to reduce and ultimately reverse the accumulation of anthropogenic CO_2 in the oceans, and to mitigate the climate crisis, is to drastically cut emissions. The risks for natural and human systems are significantly lower for global warming of 1.5°C than at 2°C, meaning countries must act now.

- Ocean sanctuaries, i.e. fully protected marine reserves where all extractive activities are prohibited, increase the coping capacity of marine life to the multiple stresses unleashed by climate change, ocean acidification and deoxygenation.

- Establishing a global network of ocean sanctuaries encompassing a portfolio of ecosystems is vital to safeguarding natural stores of CO_2 in the ocean ('blue carbon') and the ecosystems and processes which contribute to their accumulation—thus keeping the planet healthy, and protecting the livelihoods of the millions of people who depend on healthy oceans.

- A robust Global Ocean Treaty must be agreed in 2020 to safeguard and restore the health of our oceans, and pave the way for the establishment of a network of ocean sanctuaries in international waters.

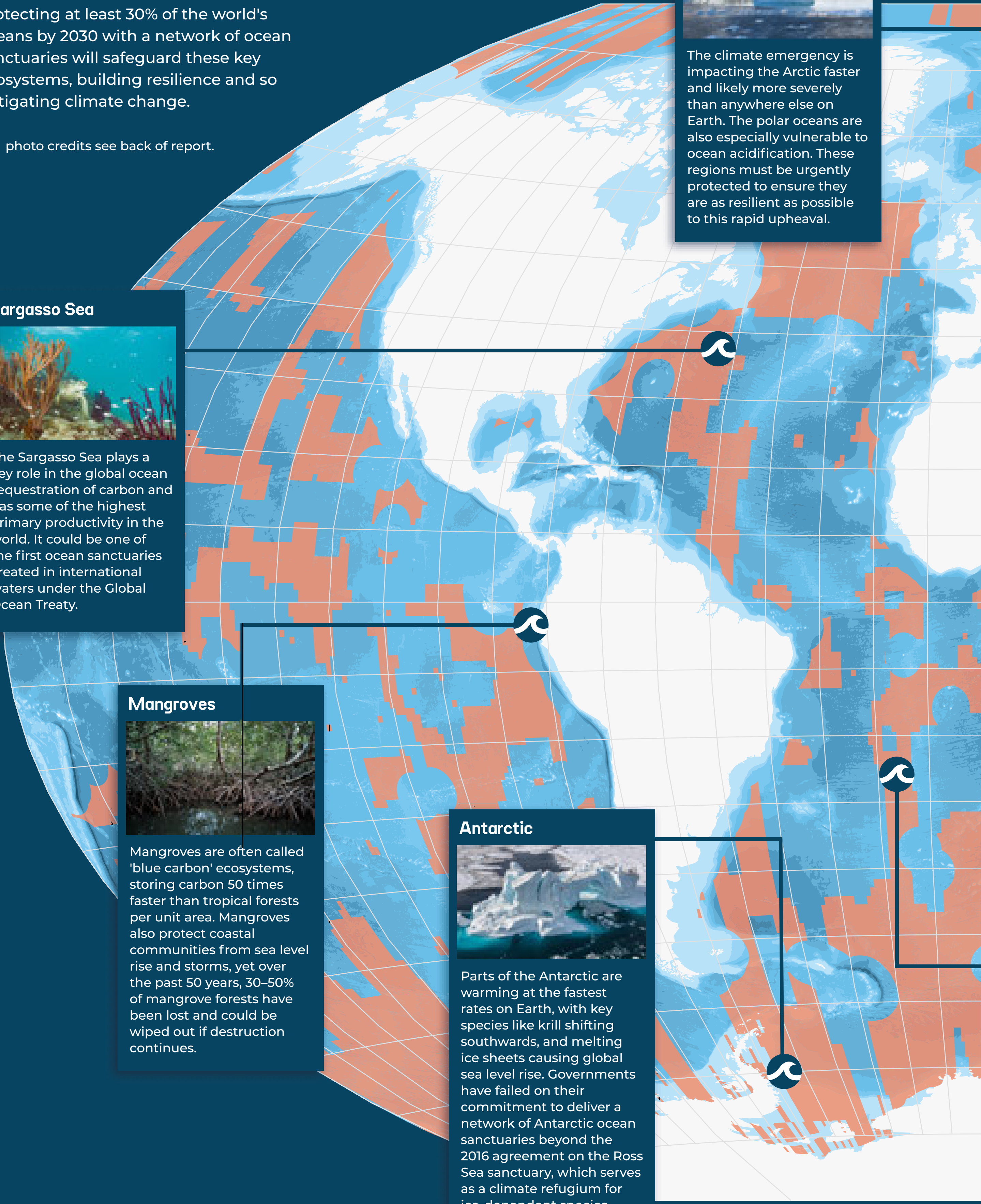
- At the 2020 Convention on Biological Diversity Conference of the Parties (COP 15), governments must agree to globally binding targets for the protection of at least 30% of the ocean by 2030 through the establishment of networks of ocean sanctuaries, with the remaining 70% of the ocean sustainably managed.

- Deep sea mining poses a risk to deep sea biodiversity and processes, including carbon sequestration and burial in the deep sea. A ban on deep sea mining is required as it has not been clearly demonstrated that it can be managed in such a way that does not disrupt ecosystem functions, ensures the effective protection of the marine environment and prevents loss of biodiversity.

ECOSYSTEMS AT THE FRONTLINE OF THE CLIMATE CRISIS

Protecting at least 30% of the world's oceans by 2030 with a network of ocean sanctuaries will safeguard these key ecosystems, building resilience and so mitigating climate change.

For photo credits see back of report.



Arctic

The climate emergency is impacting the Arctic faster and likely more severely than anywhere else on Earth. The polar oceans are also especially vulnerable to ocean acidification. These regions must be urgently protected to ensure they are as resilient as possible to this rapid upheaval.

Sargasso Sea

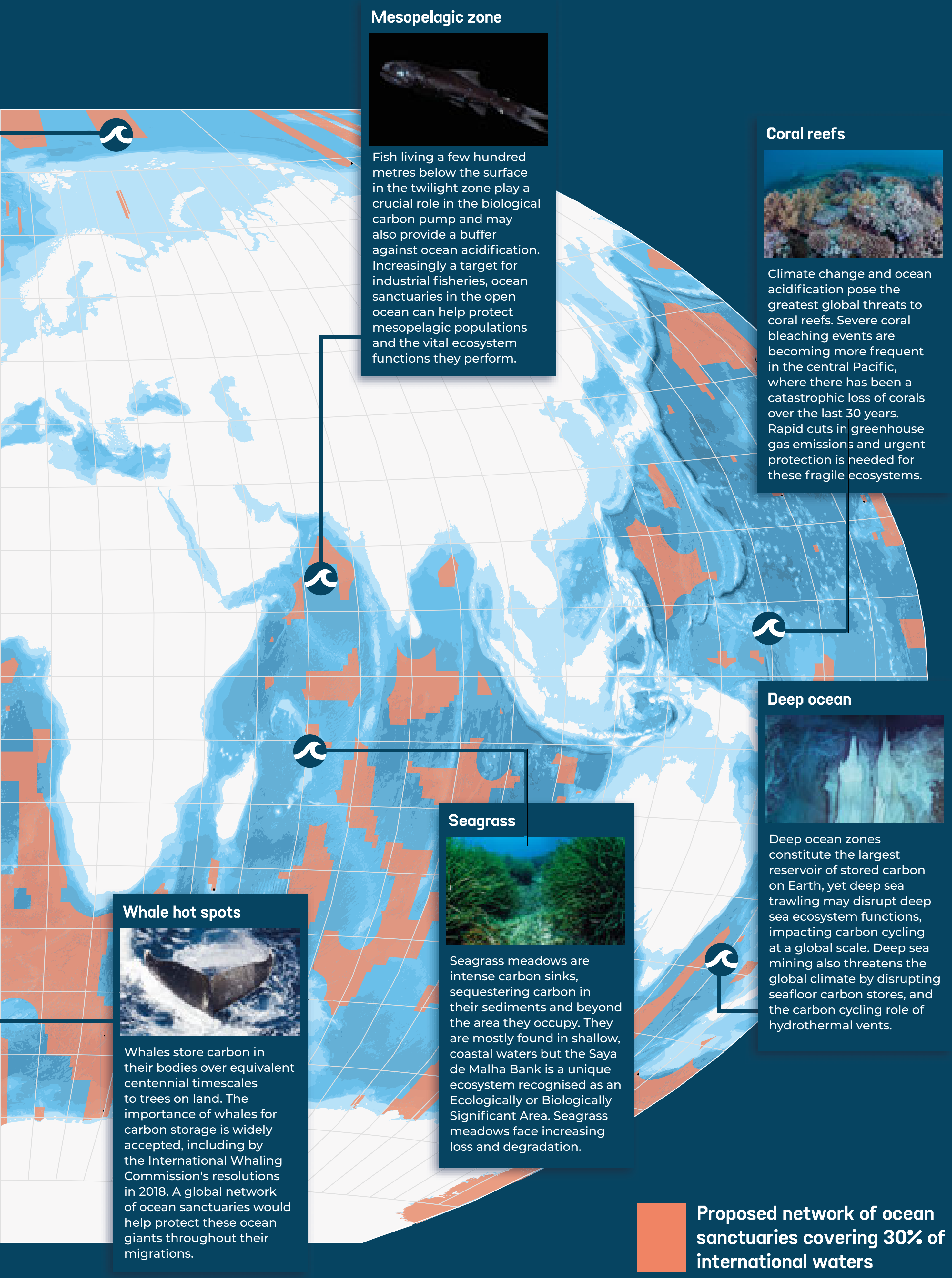
The Sargasso Sea plays a key role in the global ocean sequestration of carbon and has some of the highest primary productivity in the world. It could be one of the first ocean sanctuaries created in international waters under the Global Ocean Treaty.

Mangroves

Mangroves are often called 'blue carbon' ecosystems, storing carbon 50 times faster than tropical forests per unit area. Mangroves also protect coastal communities from sea level rise and storms, yet over the past 50 years, 30–50% of mangrove forests have been lost and could be wiped out if destruction continues.

Antarctic

Parts of the Antarctic are warming at the fastest rates on Earth, with key species like krill shifting southwards, and melting ice sheets causing global sea level rise. Governments have failed on their commitment to deliver a network of Antarctic ocean sanctuaries beyond the 2016 agreement on the Ross Sea sanctuary, which serves as a climate refugium for ice-dependent species.



Mesopelagic zone

Fish living a few hundred metres below the surface in the twilight zone play a crucial role in the biological carbon pump and may also provide a buffer against ocean acidification. Increasingly a target for industrial fisheries, ocean sanctuaries in the open ocean can help protect mesopelagic populations and the vital ecosystem functions they perform.

Coral reefs

Climate change and ocean acidification pose the greatest global threats to coral reefs. Severe coral bleaching events are becoming more frequent in the central Pacific, where there has been a catastrophic loss of corals over the last 30 years. Rapid cuts in greenhouse gas emissions and urgent protection is needed for these fragile ecosystems.

Deep ocean

Deep ocean zones constitute the largest reservoir of stored carbon on Earth, yet deep sea trawling may disrupt deep sea ecosystem functions, impacting carbon cycling at a global scale. Deep sea mining also threatens the global climate by disrupting seafloor carbon stores, and the carbon cycling role of hydrothermal vents.

Seagrass

Seagrass meadows are intense carbon sinks, sequestering carbon in their sediments and beyond the area they occupy. They are mostly found in shallow, coastal waters but the Saya de Malha Bank is a unique ecosystem recognised as an Ecologically or Biologically Significant Area. Seagrass meadows face increasing loss and degradation.

Whale hot spots

Whales store carbon in their bodies over equivalent centennial timescales to trees on land. The importance of whales for carbon storage is widely accepted, including by the International Whaling Commission's resolutions in 2018. A global network of ocean sanctuaries would help protect these ocean giants throughout their migrations.

🟥 **Proposed network of ocean sanctuaries covering 30% of international waters**

Mangroves in Komodo National Park, Indonesia
© Paul Hilton / Greenpeace

BLUE CARBON: KEEPING THE PLANET HEALTHY

A network of ocean sanctuaries covering at least 30% of the world's oceans needs to prioritise the protection of those marine ecosystems that are crucial to keeping the planet healthy through their ability to absorb and store carbon. This section outlines those ecosystems with the greatest blue carbon potential. The ocean is an integral part of the Earth's carbon cycle and is estimated to absorb 2 ± 0.8 billion tons of carbon each year, capturing 20–30% of total carbon dioxide emissions from human activities since the 1980s.[11] This facility reduces the rate of increase of net atmospheric CO_2 and slows global warming. Yet there is a flipside: elevated levels of CO_2 are causing substantial changes in marine physics, chemistry and biology, with ocean warming, acidification and deoxygenation compromising the ability of the ocean to keep this blue planet healthy by maintaining vital ecosystem structures and processes.[12]

The Earth's largest carbon sink

A complex suite of physical and biological processes govern the movement of carbon between different areas of the ocean and the transfer of atmospheric carbon from the surface to the deep ocean where it can be sequestered for millennia. These deep ocean zones constitute the largest reservoir of stored carbon on Earth, storing more than 50 times the amount of carbon in the atmosphere and more than 10 times the amount of carbon held in terrestrial vegetation, soils and microbes combined.[13]

Inorganic carbon

The vast majority of carbon in the ocean is in the form of inorganic compounds (carbonic acid, bicarbonate ions and carbonate ions) resulting from atmospheric CO_2 dissolving in the surface waters of the ocean, a process known as the solubility pump. The CO_2 absorbed by the ocean is not evenly distributed and some oceans have a higher concentration of dissolved CO_2 than others. For example, the North Atlantic stores 23% while the Pacific, despite being the largest ocean, absorbs just 18%.[14,15] Ocean currents transport warm water from tropical regions towards colder areas at the poles, during which time the sea water cools and absorbs atmospheric CO_2. This CO_2 dissolves twice as readily in cold water at the poles than in warm waters near the equator. Cool water at the poles sinks to the deep sea, taking with it the dissolved CO_2 where it may remain locked away from the atmosphere for hundreds to thousands of years. The transport of carbon to the deep sea through the mixing of layers of the ocean is sometimes referred to as the physical pump. Continued carbon and heat uptake by the ocean throughout the 21st century will exacerbate stratification, ocean acidification and a decline in oxygen content and carbon export, which would be greater under high emission scenarios.[16]

Biological component of ocean carbon

Within the global carbon cycle, the proportion of organically-bound, biologically 'fixed' carbon found in marine organisms and sediments is much smaller than the inorganic carbon dissolved in seawater. However, it is an integral and significant part of the cycle. Carbon sequestered long-term in the seabed is known to come from sources within the open ocean and coastal ecosystems, but the links between these sources and the rates of sequestration are as yet poorly characterised.[17] Importantly, the biological component, if properly protected and/or allowed to recover from damage and degradation—such as through a network of ocean sanctuaries—could play a vital role in mitigating the scale and resulting impacts of climate change and ocean acidification.

> "Blue carbon ecosystems constitute the largest reservoir of stored carbon on Earth, storing more than 50 times the amount of carbon in the atmosphere and more than 10 times the amount of carbon held in terrestrial vegetation, soils and microbes combined."

Coastal 'blue carbon' ecosystems

Three vegetated coastal ecosystems—mangrove forests, saltwater marshes and seagrass meadows—are widely regarded in scientific literature as being key to removing CO_2 and are commonly referred to as 'blue carbon' ecosystems. Some of the organic carbon forms that originate in these vegetated coastal ecosystems are exported to the deep sea, and some remain in the coastal regions. Unlike terrestrial soils, the sediments in which healthy salt marsh plants, mangrove and seagrasses grow do not become saturated with carbon. The sediments accrete vertically with a rising sea level, meaning that the rate and quantity of carbon sequestration can increase over time.[18]

Less is known about the role of macroalgae (seaweeds) and seaweed-dominated ecosystems, such as kelp forests, which exhibit very high rates of growth and primary productivity but do not sequester carbon in situ. However, these ecosystems likely play an important role as a source of organic carbon that may be sequestered elsewhere in the ocean.[19, 20]

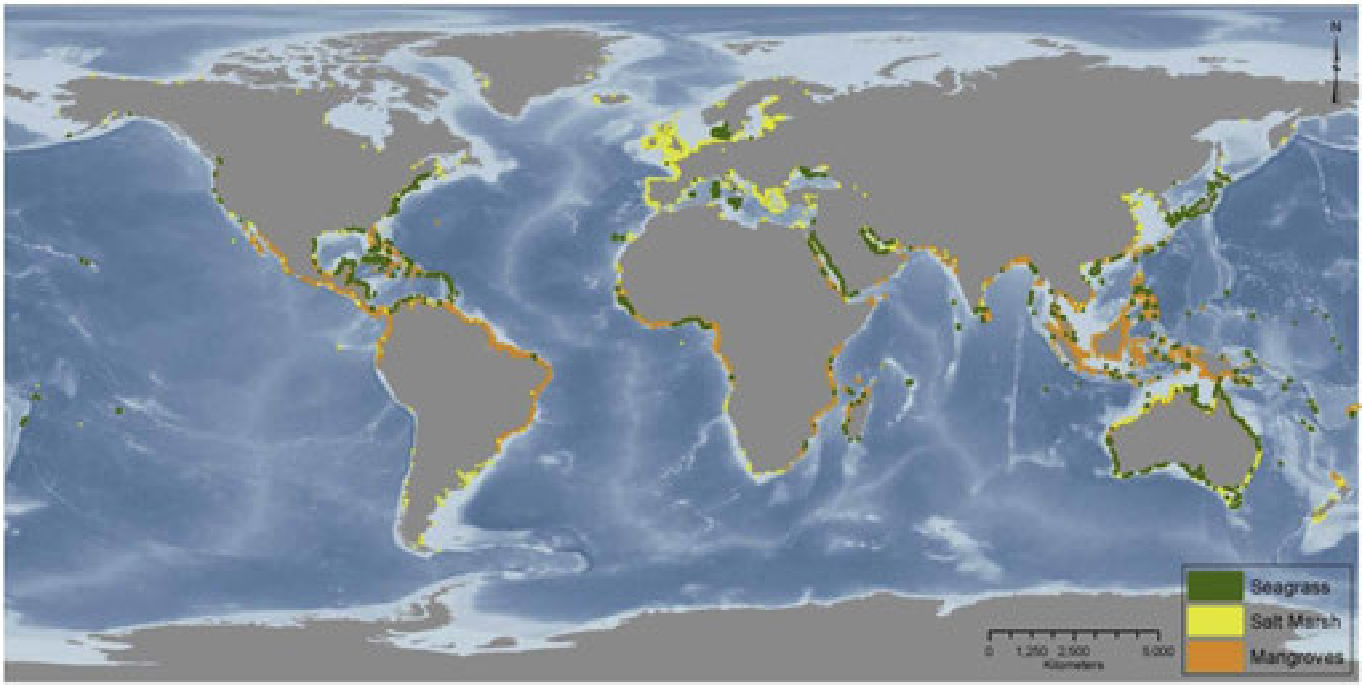
Furthermore, these blue carbon ecosystems provide essential benefits for climate change adaptation, including coastal protection and food security for many coastal communities. When these important ecosystems are damaged or lost, not only is their carbon sink capacity lost or adversely affected, but carbon stored in the soil and the living biomass is released, resulting in emissions of CO_2 and so exacerbating climate change.

Mangroves

Mangroves are found along the coasts and estuaries of 118 tropical and subtropical countries situated within 30° of the equator and have evolved special features that enable them to thrive in saltwater.[22] Mangrove ecosystems are highly productive and biologically rich, providing homes and feeding grounds for a wide range of species, many of which are endangered.[23] Leaves and branches that fall from the mangroves are broken down by bacteria, giving mangroves their distinctive odour and so providing the nutrients that are the base of the mangrove food web.

Mangrove forests are not only highly important for wildlife but they are also critically important to people. A 2014 report by the United Nations Environment Programme (UNEP) suggested that the number of people living within 10 km of significant mangrove areas might rise to 120 million by 2015.[24] The majority of these people reside in developing countries in Asia, West Africa and Central Africa, and are dependent on the mangrove forest for their daily sustenance and livelihoods.

Mangroves are particularly important as fish spawning grounds and nurseries and therefore provide food security for neighbouring communities. But it is not only fish that people derive from mangroves. These ecosystems also provide timber for buildings, fodder for animals, medicinal plants and charcoal for cooking. Crucially, mangroves also provide important supporting services including coastal protection, water quality maintenance and erosion control.[25]



Blue carbon ecosystems. Source: Pendleton et al. (2012)[21]

> "The rate of carbon storage in mangrove ecosystems is approximately 10 times greater than in temperate forests and 50 times greater than in tropical forests per unit area."

Mangroves in Laguna de Términos, Mexico
© Tomas Bravo Garcia / Greenpeace

Mangroves are highly carbon-dense forests and for this reason are an important carbon reserve.[26] Mangrove trees store carbon equally between the roots, leaves and wood but, in mangrove habitats, the majority of carbon is actually stored not in the living biomass but in the soil and in the dead, underground roots.[27] The rate of carbon storage in mangrove ecosystems is approximately 10 times greater than in temperate forests and 50 times greater than in tropical forests per unit area.[28] Mangroves store more carbon per unit area (956 Mg C ha−1) than saltmarshes (593 Mg C ha−1), seagrasses (142 Mg C ha−1), peat swamps (408 Mg C ha−1) and terrestrial rainforests (241 Mg C ha−1) do. And although mangroves occupy only 1.9% of the tropical and subtropical coast, this ecosystem accounts for 5% of net primary production of carbon and 30% of all coastal ecosystems' carbon burial.[29] These characteristics should make the protection of mangroves from human activity a priority for relevant governments.

Salt marsh

Tidal salt marshes are intertidal systems that are found from sub-Arctic to tropical climates, with the most extensive coverage in temperate regions. Salt marsh ecosystems are physically dominated by vascular plants but also include other primary producers (macroalgae, phytoplankton and cyanobacteria). The marsh's plants take in CO_2 from the atmosphere (rather than the sea) and rates of above-and-below ground carbon sequestration vary across plant families and regions. Each molecule of CO_2 sequestered in tidal salt marsh soil (and also in mangroves, which replace salt marshes in the subtropics) has a greater 'value' than any other ecosystem due to the lack of production of other greenhouse gases. This is because sulphates present in salt marshes reduce the activity of microbes that produce methane.[30]

Sea thrift on a salt marsh on the North Sea coast
© Bernhard Nimtsch / Greenpeace

Posidonia oceanica meadows in Sardinia
© Egidio Trainito / Greenpeace

Seagrass

Seagrasses are a functional group of about 60 species of underwater flowering plants. Seagrasses create a complex three-dimensional habitat in otherwise structurally limited systems which support a wide array of other species.[31] Seagrass ecosystems are mostly found in shallow, coastal waters, at depths of around 60 m, in every continent except Antarctica. However, the largest contiguous seagrass beds in the world cover the largest submerged bank in the world, the Saya de Malha Bank, which is located in international waters northeast of Madagascar, between the Republic of Seychelles and the Republic of Mauritius. As a seagrass-dominated ecosystem located in the high seas, the Saya de Malha Bank is a unique ecosystem and in recognition of this was accepted as an Ecologically or Biologically Significant Area (EBSA) by the Convention on Biological Diversity (CBD) in 2014.[32] Seagrass ecosystems, like mangroves, are of global significance to our climate and food security but have not been given the attention by scientists that they warrant given the direct and indirect benefits they deliver to human wellbeing.[33]

Seagrass meadows have also been identified as intense carbon sinks, accumulating large carbon stocks in their sediments.[34] Carbon sequestration is known to vary among species in different regions and within the meadow landscape itself.[35, 36, 37] Various factors including depth, water turbidity, wave height, canopy complexity and bioturbators (organisms that contribute to the rearrangement and aeration of marine sediments) will all affect carbon sequestration.[38, 39, 40]

> "Posidonia oceanica meadows have been shown to store carbon for thousands of years in their soils, which have been found to be as much as 11 m deep."

The Mediterranean seagrass *Posidonia oceanica* is relatively well-studied compared to other species and *Posidonia oceanica* meadows have been shown to store carbon for thousands of years in their soils, which have been found to be as much as 11 m deep.[41, 42] However, only some of the organic carbon produced by seagrasses is sequestered in the underlying sediments, with about a quarter (24.3% on average) exported to adjacent ecosystems.[43] While some of the exported carbon is decomposed or incorporated in marine food webs, some will become buried in sediments in other ecosystems. A study published in 2017 examining the contribution of seagrass meadows to marine carbon sequestration conclusively demonstrated that seagrass meadows sequester carbon beyond the area they occupy, contributing to the process in estuarine, shelf and deep-sea sediments.[44] The implication of the study's finding is that the contribution of seagrass meadows to carbon sequestration has been underestimated by only including carbon burial within seagrass sediments.

The connectivity between coastal and offshore ecosystems in the carbon cycle

Marine ecosystems can be considered ‘open’ systems in that they exhibit high rates of the transfer of energy, matter, genetic material and species across regional seascapes. Appreciating this connectivity is crucial to understanding carbon cycling and natural carbon sequestration in the ocean and to understanding the need for a network of ocean sanctuaries. Marine ecosystems can function as ‘fixers’, ‘donors’ and ‘recipients’ of carbon and a proportion of the carbon fixed by the vegetative coastal ecosystems described above is transported to other ocean ecosystems.

Collectively, vegetated coastal habitats, including seagrass and macroalgal beds, mangrove forests and salt marshes, cover ~ 7 million km^2 and support about 1–10% of the global marine net primary production. About 40% of the organic carbon that they fix is either buried in sediments within these habitats or exported away.[45] Uncertainties as to the area covered by vegetated coastal habitats, combined with differing estimates for carbon flux, result in a 10-fold bracket around the estimates of their contribution to organic carbon sequestration in sediments and the deep sea. These range from 73 to 866 Tg C yr^{-1}, representing between 3% and ⅓ of oceanic CO_2 uptake.[46] Up to half of this carbon sequestration occurs in sink reservoirs (sediments or the deep sea) beyond these habitats.

Quantifying the contributions of blue carbon ecosystems to the sequestration of organic carbon in other habitats is challenging. Various complementary methods including bulk isotopes, compound-specific isotopes, biomarkers, molecular properties, and environmental DNA (eDNA) are being used to trace the movement of organic carbon through the marine environment.[47] Understanding the provenance and fate of organic carbon will help decision-making with regard to conservation and restoration schemes aimed at enhancing blue carbon sequestration, and avoiding greenhouse gas emissions.

The biological pump

Marine organisms in the open ocean also play a critical role in the global carbon cycle and the capture and storage of carbon in the deep ocean via the biological carbon pump (BCP).

In sunlit waters above 200 m, phytoplankton such as algae use photosynthesis to transform dissolved CO_2 into organic carbon, whereby marine food webs develop. Marine species at all levels in the food web are vital to the retention, cycling and long-term storage of blue carbon and its transfer from the surface to deep ocean waters and sediments. As fixed carbon passes through food webs, a very large proportion is converted back into CO_2 through respiration and is lost again to the atmosphere. However, some of the organic matter formed in the upper ocean becomes particulate organic carbon (POC)—organic matter that can’t be passed through a filter—and a small fraction of this is transported to deep waters (>1000 m), where some is sequestered from the atmosphere over long timescales. Long-term carbon sequestration, whereby microbial degradation of organic matter gives rise to gas hydrates, and carbon from decomposed plankton is mineralised to form oil, may take millions of years. Approximately 1% of the total annual organic carbon production at the sea surface is buried in the sediment.[48] It has been estimated that without the biological carbon pump, present day atmospheric CO_2 concentrations would be approximately 200ppm (~50%) higher.[49]

A key mechanism for the transport of POC to the deep ocean is the biological gravitation pump (BGP). Over days and weeks, this mechanism sinks pieces of phytoplankton, zooplankton faecal matter, dead microorganisms and other bits of biological debris vertically down the water column, where they become food for deep water and bottom dwelling organisms. Measurements show that the BGP accounts for about half the carbon sequestered by the biological pump, the rest resulting from particle injection pumps (PIPs) —the name given to a range of physical and biological mechanisms that move carbon, including ocean eddies and daily vertical migration of zooplankton. This describes the phenomenon whereby zooplankton inhabiting the mesopelagic zone (i.e. the layer of ocean between 200 m and 1000 m deep where little light penetrates, also known as the ‘twilight zone’) ascend to the surface of the ocean at night to graze on phytoplankton and smaller zooplankton. They then descend again during the day to deeper waters, where they are less likely to be eaten and where they respire CO_2 and excrete organic carbon. This diel vertical migration is said to be the largest migration on Earth.[50] In April 2019, a review article in the journal Nature showed the complex and four-dimensional nature of the various PIPs and how multiple processes interact and feed back on each other over time.[51] Understanding these processes is vital to generating better models and better predicting how the ocean will respond to a changing climate.[52]

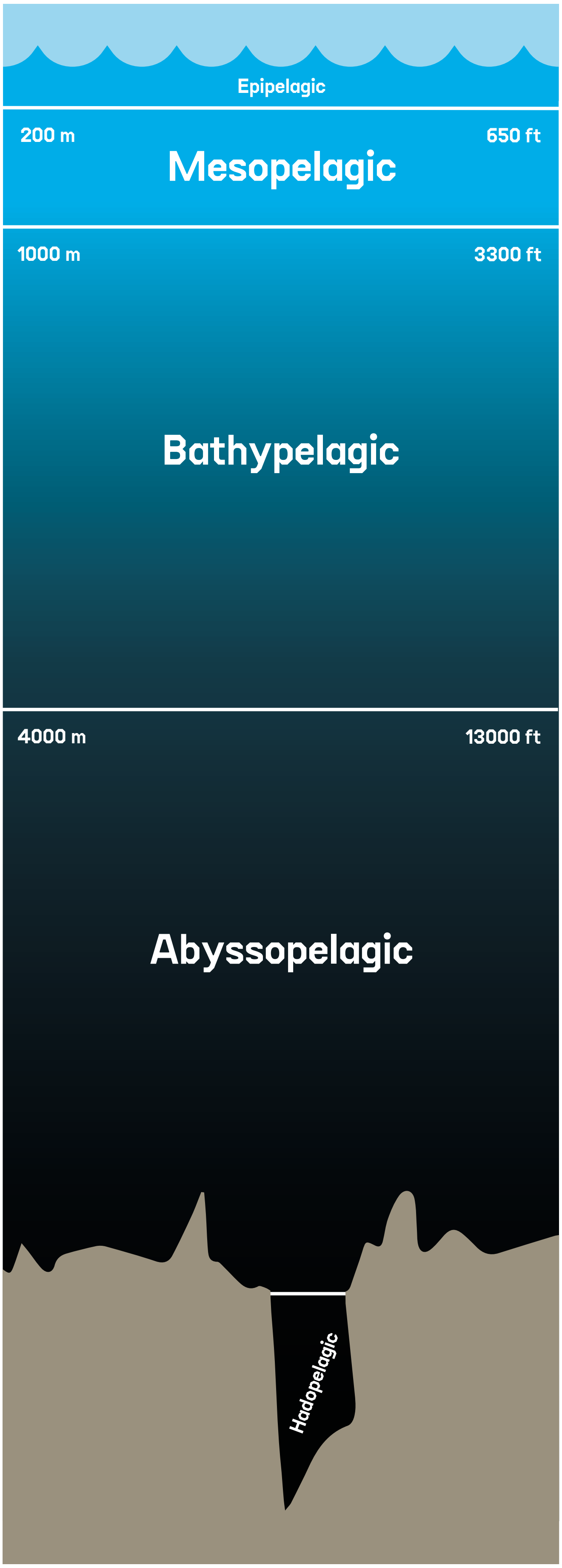
Antarctic krill
© Christian Åslund / Greenpeace

Krill and mesopelagic fish —key species in carbon cycling

The community of organisms inhabiting the mesopelagic zone are important in carbon sequestration because the foraging behaviour of many mesopelagic species moves carbon from the surface to deeper waters. Mesopelagic organisms repackage organic carbon into faecal pellets that sink more quickly than the original material and break up large, aggregated particles into smaller particles.[53, 54]

Mesopelagic fish play a crucial role in the biological carbon pump and have long been thought to dominate the world's fish biomass. Estimates derived from sampling with trawl nets put the total biomass at ~1000 million tonnes, whereby lantern fish (*Myctophidae*) dominate.[55] However, this figure has been challenged and is now thought to be an underestimation of about an order of magnitude out.[56]

In the Southern Ocean, the huge number and biomass of Antarctic krill, coupled with their behavioural patterns whereby krill undertake significant daily migrations through the water column, suggest that krill play an important role with respect to global carbon.[57, 58] The high density of individuals in krill swarms likely results in a 'rain' of faecal pellets (marine snow) which may overload detrital zooplankton that consume the faecal pellets, causing them to pass mostly undisturbed through the upper mesopelagic. This would explain the high numbers of krill pellets collected in sediment traps in the meso-and-upper bathypelagic zones (i.e. down to 4000 m). Recent research shows that krill faecal pellets can make up a large component of the carbon flux in the South Orkneys marginal ice zone region in spring.[59]



Ocean zones, graphic adapted from Wikipedia.

The role of large vertebrates in carbon cycling and sequestration

The role that large vertebrates have in the cycling and sequestration of carbon in the marine environment is poorly understood, but this is beginning to change. Research over the last decade is unveiling how vertebrate activity and natural life processes provide pathways, pumps and trophic cascades that enhance uptake and long-term storage of atmospheric carbon by plankton. This facilitates the transport of biological carbon from the ocean surface to deep water and sediment.[60]

As large vertebrates move both horizontally and vertically through the marine environment, they are moving carbon. While carbon stored in the biomass of marine vertebrates is viewed as ‘temporary carbon’, the largest and the longest-lived of these animals, such as baleen whales, store carbon over equivalent centennial timescales to trees on land. Scientists have estimated that populations of large baleen whales now store 9.1×10^6 tons less carbon than before commercial whaling and that rebuilding whale populations would remove 1.6×10^5 tons of carbon each year through sinking whale carcasses, equivalent to preserving 843 hectares of forest each year.[61]

Marine vertebrates also enhance the uptake of carbon through ‘biomixing’, which describes the process of animals mixing, through turbulence and drag, nutrient-rich water throughout the water column, stimulating primary production by phytoplankton in otherwise nutrient-poor waters.[62] Research shows that the loss of biomixing through decimation of populations of big fish and whales over the past couple of centuries could have had effects on our climate.[63]

> "Scientists have estimated that populations of large baleen whales now store 910 million tons less carbon than before commercial whaling and that rebuilding whale populations would remove 160,000 tons of carbon a year."

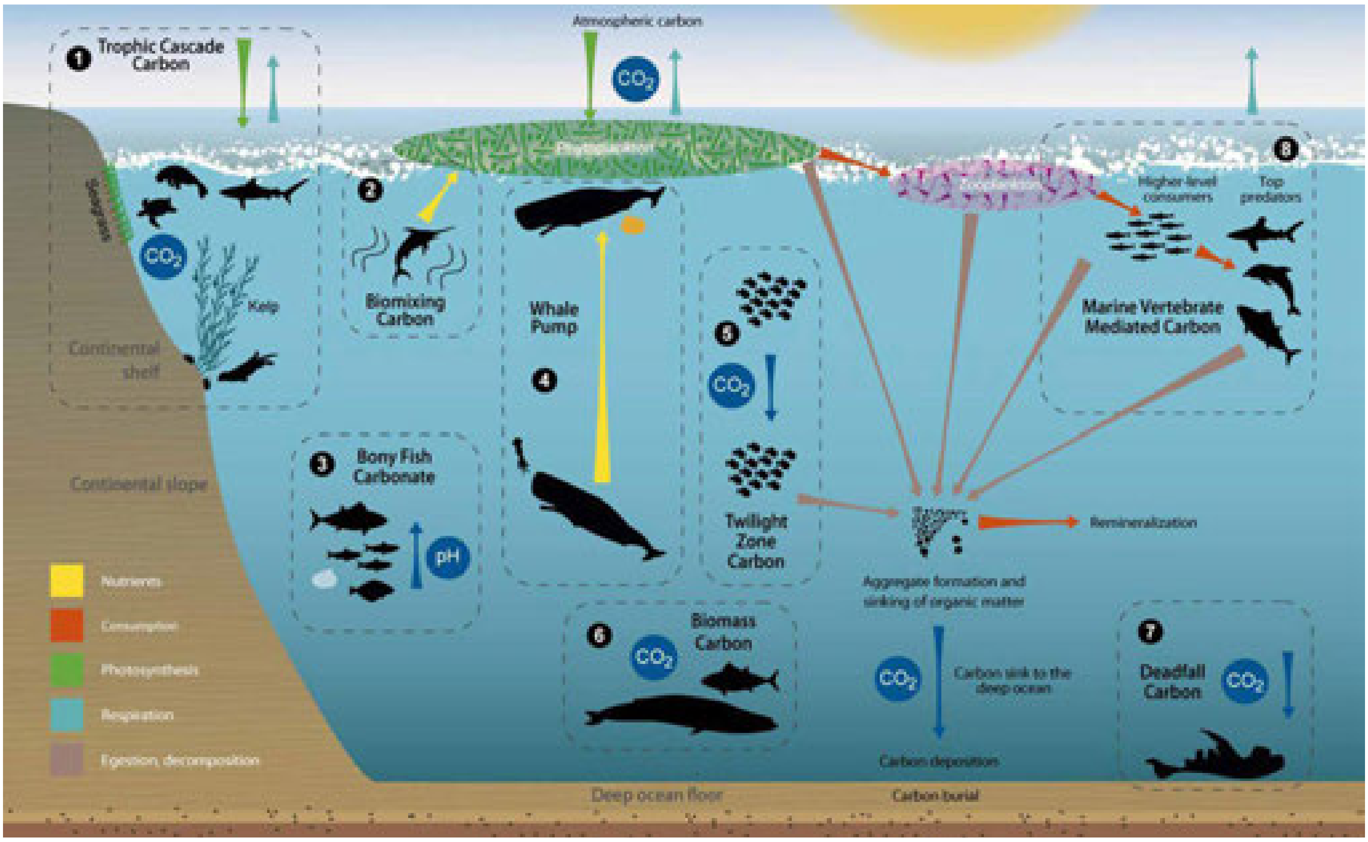
Large whales are particularly important ‘ecosystem engineers’, helping maintain healthy ecosystems through the redistribution of nutrients both vertically and horizontally through the ocean.[64] When whales return to the surface from feeding at depth, the faecal matter they release in shallow water supplies iron and nitrogen to microorganisms there. This is known as the ‘whale pump’. A similar process called the ‘great whale conveyor’ also operates, whereby some species of whale, such as humpback whales, redistribute nitrogen and other nutrients from their rich feeding grounds near the poles to their warmer, low latitude, nutrient-poor breeding and calving grounds. This happens through the release of their urea, dead skin cells and placentas. Through these processes whales may help to buffer marine ecosystems from destabilising stresses and enhance rates of productivity in locations where they aggregate to feed and give birth. The importance of whales for carbon storage is now so widely accepted that the International Whaling Commission passed two resolutions in 2018 recognising their value with clear implications for future management.[65]

A baleen whale in international waters
© Alex Hofford / Greenpeace

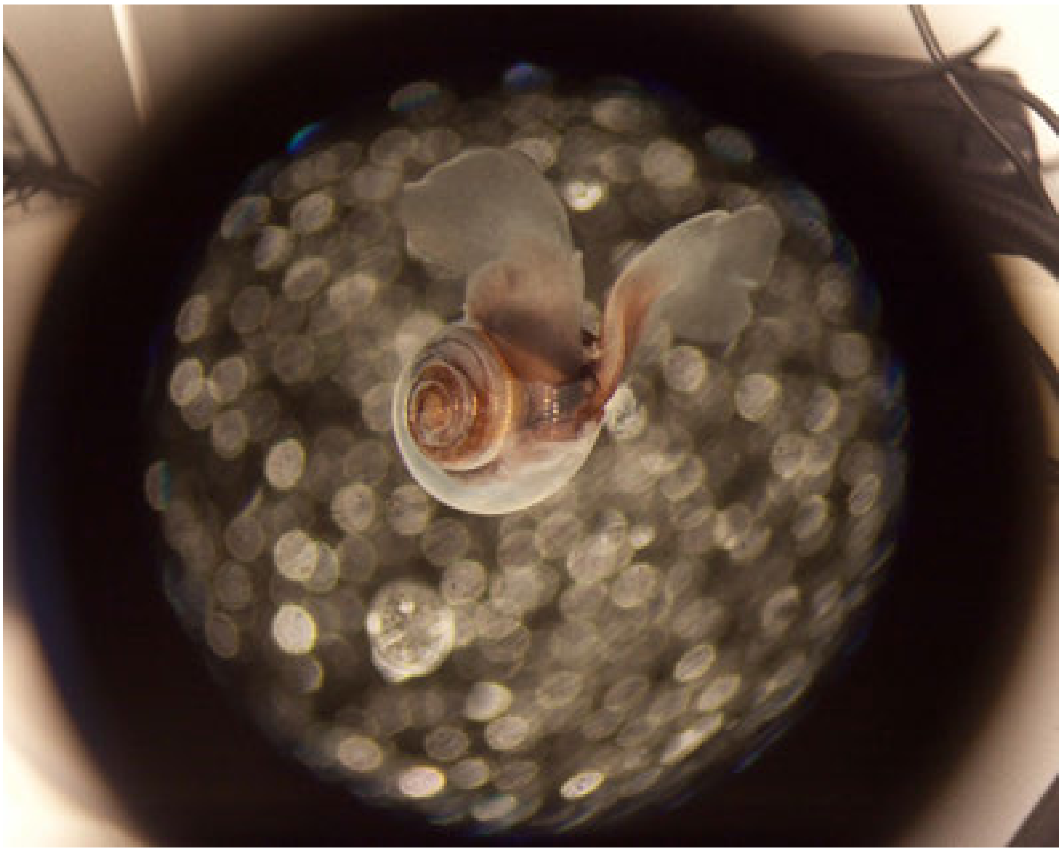
> "The movement of marine species, such as billfish, tuna, sharks, and rays, suggest it is likely that they, like mesopelagic fish and whales, also influence carbon cycling in the open ocean."

Studies of the coastal vegetative ecosystems explored earlier in this report have pointed to the critical importance of predation by grazing animals in maintaining and increasing reserves of blue carbon.[66] Although the roles of top predators in the carbon and other biogeochemical cycles are largely unquantified, the movement of marine species, such as billfish, tuna, sharks, and rays—which often travel great distances across the ocean and may dive deep into the meso and even bathypelagic realms—suggest it is likely that they, like mesopelagic fish and whales, also influence carbon cycling in the open ocean.[67]

Manta Rays off the coast of Nusa Penida, Indonesia
© Paul Hilton / Greenpeace



Marine vertebrate carbon services: eight carbon pathways, pumps and trophic cascades. Source: Lutz and Martin (2014)[68]



A 'scientist's eye view' of a pteropod, or sea butterfly
© Nick Cobbing / Greenpeace

Carbonate pump

There is a carbonate pump by which various open ocean calcifiers—organisms that form shells and structures of calcium carbonate ($CaCO_3$)—act as significant carbon pools, transporting calcium carbonate through the water column to the deep sea and its sediments for long-term geological storage.[69] These calcifiers include coccolithophores (a type of phytoplankton), pteropods (a type of zooplankton) and foraminifera (single-celled animals which are mostly benthic but can be planktonic). Coccolithophores are enclosed in a mosaic, or cage, of microscopic plates made from calcium carbonate. Similarly, some pteropods—sometimes referred to as sea butterflies—have a calcium carbonate shell and foraminifera possess a hard shell made from calcium carbonate. Although the process of calcification itself leads to the release of carbon dioxide from dissolved inorganic carbon in seawater, some shells of these organisms will reach the bottom of the ocean. Eventually, tectonic processes of high heat and pressure transform calcium carbonate sediments into limestone. While the main source of calcium carbonate in the ocean comes from the shells of calcifying planktonic organisms, bony fish (rather than the cartilaginous sharks and rays) precipitate carbonates within their intestines and excrete these at high rates. It has been estimated that marine fish contribute 3–15% of total oceanic carbonate production and this helps provide a pH buffer against ocean acidification.[70]

Storage in deep sea ecosystems

Although scientific uncertainties surrounding quantitative estimates of carbon storage within many marine and deep sea ecosystems remain high, it is without doubt that these ecosystems play an important and irreplaceable role in cycling and storing carbon over short, medium and long timescales. It should also be noted that the amount of carbon in the ocean, and the amount that is sequestered in sediments, varies spatially and temporally. Carbon cycling is highly dynamic, and some areas of the seabed can be either a net sink or source of carbon depending upon season, sea-surface temperature, ocean currents and turbulence from storms.[71] It is clear therefore that more research, including long-term and more geographically comprehensive monitoring, is needed to fully understand the processes that drive these changes.[72]

> **"It has been estimated that marine fish contribute 3–15% of total oceanic carbonate production and this helps provide a pH buffer against ocean acidification."**

The aftermath of Hurricane Sandy in New Jersey, U.S.
© Tim Aubry / Greenpeace

THE IMPACTS OF INCREASING FOSSIL FUEL EMISSIONS

Climate change

In its 2014 summary for policymakers, the IPCC boiled down the impacts of climate change on marine systems over the next few decades to the text set out below, attributing degrees of confidence to the various broadscale predictions.[73]

> **'Due to projected climate change by the mid-21st century and beyond, global marine-species redistribution and marine-biodiversity reduction in sensitive regions will challenge the sustained provision of fisheries productivity and other ecosystem services (*high confidence*). Spatial shifts of marine species due to projected warming will cause high-latitude invasions and high local-extinction rates in the tropics and semi-enclosed seas (*medium confidence*). Species richness and fisheries catch potential are projected to increase, on average, at mid and high latitudes (*high confidence*) and decrease at tropical latitudes (*medium confidence*). The progressive expansion of oxygen minimum zones and anoxic "dead zones" is projected to further constrain fish habitat. Open-ocean net primary production is projected to redistribute and, by 2100, fall globally under all RCP[74] scenarios. Climate change adds to the threats of overfishing and other non-climatic stressors, thus complicating marine management regimes (*high confidence*).'**

The text, though sobering, does not fully convey the scale and scope of the changes being wrought on the ocean by climate change. The annual emission of gigatons of carbon into the atmosphere has led to a multitude of physical changes, including increasing global temperature, perturbed regional weather patterns, rising sea levels, changed nutrient loads and altered ocean circulation. This already threatens the livelihoods of millions of people globally, and poses an existential threat to many more.

> "It is clear that our addiction to fossil fuels has already irreversibly changed our blue planet."

The extent of the changes wrought on the ocean have been made explicit in the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC) which was published in September 2019.[75] One of the most worrying chapters of the report (chapter 6) examines tipping points and summarises 'abrupt and irreversible phenomena related to the ocean and cryosphere.' Among the phenomena described is the weakening by 15% of the Atlantic Meridional Overturning Circulation (AMOC), ocean currents that bring warm water to Europe. This is but one of 15 phenomena listed in the summary which form part of the scientific case for efforts to limit climate warming to well below 2°C. It is clear that our addiction to fossil fuels has already irreversibly changed our blue planet.

Furthermore, because oceanic and atmospheric gas concentrations tend towards equilibrium, increasing levels of atmospheric CO_2 drives more CO_2 into the ocean, leading to profound changes in ocean chemistry (see the section on ocean acidification).

In 2017, scientists, drawing on the results of an ensemble of 12 climate models, found that if emissions were allowed to continue on a 'business-as-usual' trajectory by 2030, 55% of the world's oceans will encounter a 'mosaic' of four major climate stressors—temperature, pH, oxygen and primary production—rising to 86% by 2050.[76] Looking further into the future, the study suggests that by 2100, nearly two-thirds of the ocean (62%) will be stressed by all four factors together. The study also shows that mitigation will slow the pace at which multiple drivers emerge, so giving more time for marine ecosystems and related socio-economic systems to adapt.

View of Hurricane Dorian from the International Space Station
© NASA

Ocean heating

The ocean absorbs almost as much CO_2 as all land-based forests and plants combined, and absorbed about 93% of the combined extra heat stored by warmed air, sea, land, and melted ice between 1971 and 2010.[77] While the upper-ocean temperature (and hence its heat content) varies over multiple time scales, including seasonal, inter-annual (such as those associated with the El Niño-Southern Oscillation), decadal, and centennial periods, all ocean basins have experienced significant warming since 1998. This warming is greatest in the Southern Ocean, the tropical/subtropical Pacific Ocean and the tropical/subtropical Atlantic Ocean.[78, 79] Between 1971 and 2010 the upper 75 m of these oceans warmed by 0.11°C [0.09 to 0.13°C] per decade.[80]

As waves, tides, and currents constantly mix ocean waters, so heat is transferred from warmer to cooler latitudes and to deeper levels, with most of the heat absorbed in the upper 700 m. The heat absorbed by the ocean is moved around the planet but is not lost to Earth. The dynamic relationship between the ocean and the atmosphere means that some of that heat will directly reheat the atmosphere. The heat already stored in the ocean will eventually be released, committing Earth to additional warming in the future.[81]

Marine heatwaves

Using a range of different temperature data sets, scientists have now conducted a comprehensive assessment of how ocean temperature extremes have been changing globally. Their findings show that, when ocean temperatures are extremely warm for an extended period of time, marine heatwaves have become more frequent and longer in duration over the past century.[82] From 1925 to 2016 global average marine heatwave frequency and duration increased by 34% and 17% respectively, resulting in a 54% increase in annual marine heatwave days globally. Significantly, the key driver for these changes is mean ocean temperature, suggesting that the trend will intensify as ocean temperatures do.[83]

An investigation into the species and ecosystem effects of marine heatwaves found that they can lead to mass dying events, species range shifts and changes to entire ecosystems and ecological processes.[84] The investigation also identified multiple regions within the Pacific, Atlantic, and Indian Oceans which are particularly vulnerable to marine heatwaves. These regions are wildlife hotspots, where many species are at the edge of their thermal limits and may also be subject to other, non-climate impacts.

The El Niño-Southern Oscillation (ENSO) and climate change

El Niño and La Niña, the warm and cold phases of what is known as the El Niño-Southern Oscillation (ENSO) cycle, are complex, natural phenomena which involve fluctuating ocean temperatures in the central and eastern equatorial Pacific, coupled with changes in the atmosphere. El Niño and La Niña events occur on average every two to seven years and usually last about a year, sometimes longer. Typically, El Niño occurs more frequently than La Niña and both can have large-scale impacts on both ocean processes and on global weather and climate. Although many regions of the world can experience disasters in any year, El Niño events may trigger flooding, drought, and fires in some countries, whilst also affecting the path and number of tropical cyclones.

During neutral and La Niña conditions, the upwelling of cold, nutrient-rich water from the deep Pacific feeds and cultivates fisheries in coastal equatorial South America, including anchoveta, the world's largest fishery. Understanding and predicting the phases of the ENSO cycle is therefore important. While scientists know that El Niño contributes to an increase in global temperatures, many are now involved in trying to determine whether rising global and ocean temperatures in turn intensify El Niño. Given the complexities involved, predictions vary, but one 2014 study suggests that super El Niño events could double in frequency in the future due to climate change.[85] New research also suggests that a weakening Atlantic Niño–Pacific connection under greenhouse warming may make it harder to predict Pacific ENSO effects.[86] Quite how naturally occurring El Niño events will unfold under climate change is uncertain and there is the attendant fear that they may interact and modify each other in ways we have never before experienced.[87]

A drought in Nong Saleek Dam, Thailand, brought on by El Niño
© Vincenzo Floramo / Greenpeace

> "Sea level rise has already been identified as having intensified the impact of Hurricane Sandy, which caused an estimated $65 billion in damages in New York, New Jersey and Connecticut in 2012."

Increase in severe storms

Global warming has perturbed weather patterns and an increase in sea surface temperature in the tropical oceans has led to an increase in the frequency of severe storms. Combing through 15 years of data obtained through the deployment of the Atmospheric Infrared Sounder (AIRS), NASA scientists have found that extreme storms—those producing at least 3 mm of rain per hour over a 25 km area—formed when the sea surface temperature was higher than about 28°C. They also found that, based on the data, 21% more storms occur for every 1°C degree that ocean surface temperatures rise.[88, 89] Should there be a 2.7 °C rise in the tropical surface temperature by the end of the century, NASA predicts that there will be a 60% increase in the frequency of severe storms. It should be noted that while the evidence points to an increase in the number of severe storms of greater intensity, the overall frequency of tropical cyclones is inhibited with greater ocean warmth.[90]

While scientists consider that it is premature to conclude with high confidence that global warming due to the burning of fossil fuels has already caused a detectable (i.e. distinguishable from natural variability) change in Atlantic hurricane activity, it is likely that global warming will cause Atlantic hurricanes in the coming century to have higher rainfall rates than present-day hurricanes, and medium confidence that they will be more intense (higher peak winds and lower central pressures) on average.[91] For example, some scientists have already concluded that global warming worsened the impacts of the recent Hurricane Dorian with warmer sea temperatures fuelling higher rainfall and stronger winds.[92]

Sea level rise, another consequence of global warming (see page 29), will exacerbate coastal inundation of tropical cyclones and hurricanes that do occur. For example, sea level rise has already been identified as having intensified the impact of Hurricane Sandy, which caused an estimated $65 billion in damages in New York, New Jersey, and Connecticut in 2012.[93]

Stronger waves

Upper-ocean warming is making waves stronger on average. Research, published in 2019 has found long-term correlations and statistical dependency with sea surface temperatures (SST), both globally and by ocean sub-basins. These correlations are particularly evident between the tropical Atlantic temperatures and the wave power in high southern latitudes, the most energetic region globally.[94] These results indicate that oceanic warming in the different ocean basins has likely led to an increase in average wave power through the influence of SST on wind patterns.

> "Today the sea is 13–20 cm higher on average than it was in 1900."

Ice melt

Measurements taken by satellite laser altimeters and at tidal stations around the world show that the global sea level is rising with regional variations and at an increasing rate.[95] The World Meteorological Organisation states that global mean sea level for 2018 was around 3.7 mm higher than in 2017 and the highest on record.[96] Between January 1993 and December 2018, the average rate of rise was 3.15 ± 0.3 mm yr^{-1}, while the estimated acceleration was 0.1 mm yr^{-2}. This may not seem like much but over time, these small increments add up so that today, the sea is 13–20 cm higher on average than it was in 1900.

Within the Earth system, the climate, the ocean and the cryosphere (those areas of the Earth where water is found in its solid state, for example in the icy polar or high-mountain regions) interact through a variety of complex processes. The cryosphere is particularly important with respect to global sea level rise.

The two major causes of global sea level rise are related to climate change. These are thermal expansion caused by ocean warming (because water expands as it warms) and increased melting of land-based ice, such as glaciers, ice caps and ice sheets.[97] It is important to note that sea ice and ice shelves already located in the ocean do not have any further significant influence on sea level after they melt. The contribution to global mean sea level rise of melting glaciers and ice sheets exceeds the effect of thermal expansion of ocean water. At present, the most significant contributors to sea level within the current climate are glaciers, but ice sheets in Greenland and Antarctica hold the potential to eventually dwarf other cryospheric contributors to sea level rise.[98] As there has been no increase in net snowfall over time, melting snow is not a factor that contributes to annual net sea level rise. At present, scientists do not know how much additional liquid water is reaching rivers and streams and eventually the sea from the melting of the permafrost.

A glacier in the Alps
© Jonas Scheu / Greenpeace

Meltwater on Greenland's ice sheet
© Nick Cobbing / Greenpeace

Worldwide, mountain glaciers are retreating and thinning and have become potent symbols of climate change. A comprehensive study of 19,000 mountain glaciers located outside of the polar regions and distinct from the Greenland and Antarctic ice sheets, has found that glacier mass loss may be larger than previously reported. It shows that present glacier mass loss is equivalent to the sea level contribution of the Greenland ice sheet and clearly exceeds the loss from the Antarctic ice sheet. This loss accounts for 25–30% of the total observed sea level rise.[99]

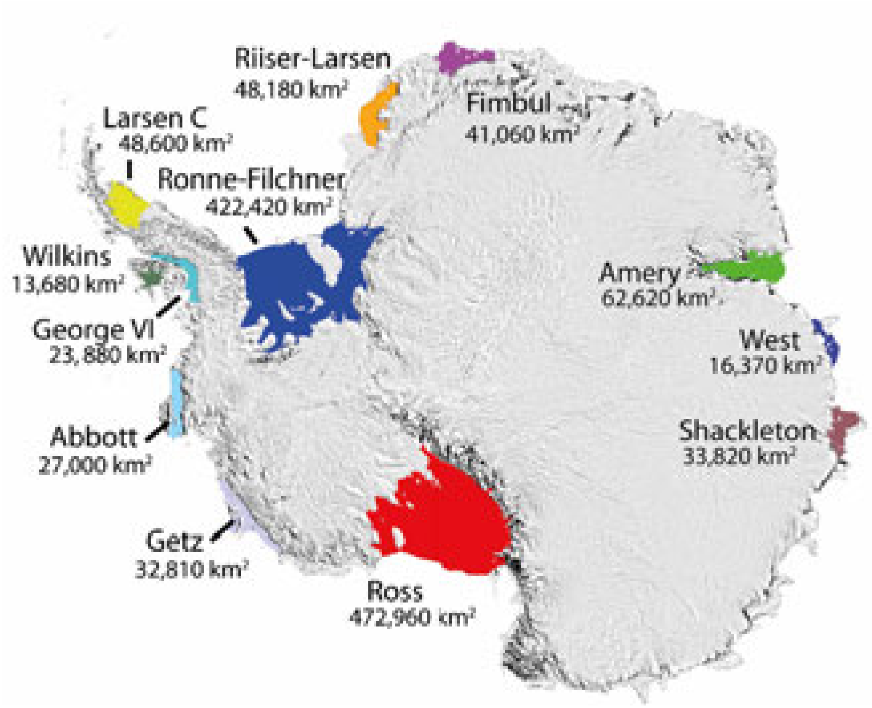
The Earth has two major ice sheets—one on Greenland and the other on Antarctica. The Greenland ice sheet is by far the smaller, covering roughly 1.7 million km^2 (650,000 square miles), whereas the Antarctic ice sheet covers nearly 14 million km^2 (5.4 million square miles).[100] For much of Greenland and Antarctica, ice flow from the central dome of the ice sheet terminates at the ocean, where it either forms a tidewater glacier which is not fully afloat, or an ice tongue/ice shelf which is comprised of thick permanent ice that is fully afloat on the ocean. It is at these edges of the polar ice sheets that we are seeing the most dramatic effects of the environmental changes that are underway. Increases in ocean heat can rapidly melt the floating ice from the underside, thinning the ice shelf and making it weaker. Additionally, fracturing of the front edge of the ice occurs as it flows over bedrock or around islands and this leads to icebergs calving into the sea.

In order to understand the role of the ice sheets in sea level rise, it is important to study the mass balance of the ice sheet, i.e. the difference between its total snow input and the total loss through combined processes, including melting, evaporation and calving. Different methods are employed to determine the ice sheet mass balance—the three main approaches being comparing outflow and melt to snowfall accumulation (the mass budget method), observing changes in glacier elevation (volume change or geodetic method) and detecting changes in the Earth's gravity field over the ice sheet (gravimetric method). Comparing and merging information derived from these methods has enabled scientists to produce best estimates for the different areas.

Scientists reconstructed the mass balance of the Greenland ice sheet for the past 46 years using improved records of ice thickness, surface elevation, ice velocity and surface mass balance of 260 glaciers. They found that the mass balance started to deviate from its natural range of variability in the 1980s.[101] The mass loss has increased by a factor of six since the 1980s and has raised sea level by an average of 13.7 mm since 1972, half of which has risen in the last eight years.

What is happening to the Greenland ice sheet is better understood than what is happening to the Antarctic ice sheet. The Antarctic ice sheet is divided into three sections: the East Antarctic ice sheet, the West Antarctic ice sheet and the Antarctic Peninsula.

Warming of the Antarctic Peninsula in the latter half of the twentieth century was greater than any other terrestrial environment in the Southern Hemisphere and warm summertime temperatures are believed to have contributed to some ice shelves in the region either calving massive icebergs or rapidly disintegrating. During the warm summers, melt ponds have formed on the ice shelf surface. Some of the meltwater in these ponds has infiltrated cracks in the ice, slicing through the shelf. This increased fracturing leads to the break-up of the shelf,[102] combined with possible changes at the ice shelf margins, such as a loss of connection with the coastline and wave action, which flexes the shelf a little. Ice shelves buttress the glaciers upstream and it has been found that the flow of the glaciers may accelerate following the break-up of an ice shelf. These highly visible events, namely Larsen Inlet ice shelf (1986/1987), Larsen A ice shelf (1995), Larsen B ice shelf (2002) and



Antarctic ice shelves. Source: Scambos T.A. et al., Remote Sensing of the Environment Vol. 111(2-3) (2007)

the north western Wilkins ice shelf (2008), have sounded the alarm with regards to the changes happening in Antarctica and the dangerous consequences, including sea level rise.

In January 2019 scientists published the longest-ever assessment of remaining Antarctic ice mass, from 1979–2017.[103] They found that Antarctica experienced a six-fold increase in yearly ice mass loss over the four-decade period, with the pace of melting rising dramatically over time. From 1979 to 2001 ice mass loss was an average of 48 gigatons annually per decade, which jumped to 134 gigatons between 2001 and 2017.[104]

Until recently, glaciologists have generally agreed that, since the late 20th century, West Antarctica has experienced ice losses while East Antarctica has experienced modest gains. However, the understanding of what is happening in East Antarctica is changing.

The assessment showed that the Wilkes Land sector of East Antarctica has, overall, always been an important contributor to Antarctic ice mass loss, even as far back as the 1980s. According to the findings, the region is probably more sensitive to climate change than has previously been assumed[105] and is especially significant because it holds even more ice than West Antarctica and the Antarctic Peninsula put together.

The study also showed that the sectors losing the most ice mass are closest to warm, salty, subsurface circumpolar deep water. As enhanced polar westerlies push more circumpolar deep water toward the glaciers, these same sectors are likely to be the most important with respect to sea level rise during future decades. Given the polar regions are warming faster than anywhere else on the planet, it is vital to put in place precautionary protection measures now to ensure they are as resilient as possible to this rapid rate of change.

A crack in the Larsen A ice shelf
© Steven Morgan / Greenpeace

Sea level rise at Satjelia island, India
© Peter Caton / Greenpeace

Sea level rise

For a variety of reasons, sea level rise doesn't happen evenly across the world—temperature, gravity and even the Earth's spin all have an influence. For example, the level in Pacific island regions was rising up to 15 mm a year between 1992 and 2009, while in some regions it dropped.[106] It is widely acknowledged that sea level rise, in combination with storm surges and coastal destruction, poses an existential threat to the Small Island Developing States (SIDS)[107] as it is estimated that at least 11–15% of the population of SIDs live on land with an elevation of 5 m or lower.[108]

The Republic of the Maldives, located in the Indian Ocean, is comprised of 1,192 widely dispersed coral islands grouped into clusters of atolls. It is the lowest-lying country on the planet, with no ground surface higher than 3 m above average sea level and 80% of the land area lying below 1 m above average sea level. Climate change is already impacting the lives of the islands' citizens, whose livelihoods in fisheries and tourism are totally dependent on the ocean. High temperatures have led to coral bleaching, while ever-higher waves are encroaching on the shores of the lowest islands and eroding beaches. When a tropical cyclone or a tsunami wave approaches, there is nowhere for residents to retreat to, and ingress of seawater is contaminating the islands' supplies of freshwater. As Abdulla Shahid, Minister of Foreign Affairs of the Maldives told a United Nations Security Council meeting on climate in January 2019, 'climate change is going to take our home away from us entirely.'[109]

Coastal ecosystems such as coral reefs, mangroves and salt marshes, which we have established are vital for carbon sequestration, storage and coastal protection, are themselves vulnerable to sea level rise. Rising sea level may impact these marine ecosystems, not only by drowning some species but by inducing changes of parameters such as available light, salinity and temperature. The scale of impact of sea level rise on these ecosystems depends on the ability of species to adapt to the rising water levels.[110]

Whether a wetland is able to withstand sea level rise will depend on the rate of the rise, its ability to keep pace vertically by sediment accretion, and the available 'accommodation space'—the vertical and lateral space available for fine sediments to accumulate and be colonised by wetland vegetation.[111] Lateral accommodation space is especially important for wetland migration if the wetland cannot keep pace with rising sea level through vertical adjustment. Unfortunately, many wetlands are constrained by levees, seawalls and other human developments that constitute a 'coastal squeeze', preventing the wetlands from migrating inland.[112]

> **"Climate change is going to take our home away from us entirely."—Abdulla Shahid, Minister of Foreign Affairs of the Maldives**

> **"In Bangladesh, a rise of 0.5 m would result in a loss of about 11% of the country's land, displacing approximately 15 million people."**

Interestingly, a new study of the carbon stored in more than 300 salt marshes across six continents has revealed that some coastal wetlands, when faced with sea level rise, respond by burying even more carbon in their soils.[113] Salt marshes on coastlines subject to sea level rise had, on average, two-to-four times more carbon in the top 20 cm of sediment, and five-to-nine times more carbon in the lower 50-100 cm of sediment, compared to salt marshes on coastlines where sea level was more stable over the same 6,000 year period.[114] This is possible because the carbon added to wetland sediment by plant growth is buried faster as the wetland becomes inundated. Trapped underwater with little to no oxygen, the organic detritus does not decompose and release carbon dioxide as quickly. This analysis shows that carbon sequestration increases according to the vertical and lateral accommodation space created by rapid sea level rise. This research adds to the existing arguments for protecting coastal wetlands because of the essential services and security they provide to coastal communities. Whether we will benefit depends entirely on how well we implement an ecosystem-based adaptation strategy that allows for wetlands to expand with sea level rise.[115]

The IPCC's Special Report on Global Warming of 1.5°C warns that catastrophic loss of ice sheets in Greenland and Antarctica, which would eventually result in many metres of sea level rise, could be triggered at around 1.5°C to 2°C of global warming.[116] The complex nature of the interaction of atmospheric warming, oceanic warming and ice sheet responses means that there are large uncertainties as to exactly what is going to happen. However, the huge risks to many people, especially those living in delta regions and low-lying coastal cities around the world, are obvious. Already, an estimated 800 million people living in more than 570 coastal cities are vulnerable to a sea level rise of 0.5 m by 2050.[117] Some east coast cities in the United States, including Baltimore and Miami, are suffering from increased 'sunny day' flooding events, i.e. tidal flooding that has been driven by rising sea levels.[118, 119] Abidjan, Accra, Alexandria, Algiers, Casablanca, Dakar, Dar es Salaam, Douala, Durban, Lagos, Luanda, Maputo, Port Elizabeth and Tunis are among the African cities that are vulnerable to sea level rise.[120] In Asia, the Krishna (India), Ganges-Brahmaputra (Bangladesh) and Brahmani (India) deltas are all highly vulnerable and in Bangladesh, a rise of 0.5 m would result in a loss of about 11% of the country's land, displacing approximately 15 million people.[121]

Villagers at Kalabogi village, Bangladesh, stand on a makeshift dike. If this dike breaks over 1,000 homes will be washed away. At high tide the sea is inches away from bursting the bank
© Peter Caton / Greenpeace

Abandoned, water-logged land where houses used to stand in Ghoramara Island, India. The island is disappearing due to coastal erosion and sea level rise
© Paul Caton / Greenpeace

Atlantic cod
© Joachim S. Mueller / CC BY-NC-SA 2.0

Leaving home: Distribution shifts in species and marine ecosystems

In response to ocean warming, marine species are already moving north or south to more favourable habitats, or to deeper, cooler waters. A 2013 meta-analysis synthesising all available studies of the consistency of marine ecological observations with expectations under climate change found that marine organisms are moving on average 75 km per decade, most usually in the direction of the poles.[122]

The movement of warm water species to temperate waters is known as 'tropicalisation'. Cases of tropical and sub-tropical species shifting their geographic range have been documented in many parts of the ocean. Regions with continuous tropical-temperate coastlines that are strongly influenced by western boundary currents are warming two to three times faster than the global mean. This means they are likely to become 'tropicalisation hotspots', the intensified currents facilitating the movement of warm water species and their larvae. These areas include Japan, eastern U.S., eastern Australia, northern Brazil and south-eastern Africa.[123] As warm water species become dominant and cooler water species recede, novel biological assemblages are coming into being and these are likely to have knock-on consequences for ecosystem function and services.[124] Cases have been documented in both Japan and the Mediterranean (where the Suez Canal enables the passage of organisms from the tropical Red Sea to the temperate Mediterranean) of invasive herbivorous tropical fish arriving and intensively grazing on kelp and other macroalgae, so changing the structure of the ecosystem.[125]

Climate change is also behind shifts in the Arctic and Southern Oceans. The main gateways into the Arctic Ocean by sub-Arctic species are through the Bering Strait for Pacific organisms and through the Norwegian and Barents Seas for Atlantic ones. Six species, including Pacific cod, walleye pollock and Bering flounder (*Hippoglossoides robustus*) are recorded by the National Oceanic and Atmospheric Administration (NOAA) as recently having extended their ranges through the Bering Strait into the Beaufort Sea.[126] On the Atlantic side, several sub-Arctic species now occur in waters around the Svalbard archipelago. In 2013, biologists reported that large numbers of juvenile Atlantic cod were present in waters around Spitsbergen.[127] Another group of researchers recorded Atlantic mackerel (*Scomber scombrus*) in Isfjorden in Svalbard for the first time. This is the northernmost record of this commercially important fish species and represents a possible northward expansion of circa 5° latitude.[128] One possible effect of ice-free summers in the Arctic Ocean is the potential for interchange of Pacific species into the Atlantic and vice versa, something that the cold temperatures and low nutrient levels of the Arctic Ocean have prevented for millennia.[129]

In the Southern Ocean, there is increasing concern about observed changes in the distribution of Antarctic krill, a keystone species which has a crucial role in the food web and plays a significant part in the transport of atmospheric carbon to the deep ocean. Data from the Scotia Sea and the Antarctic Peninsula, the region where krill is most abundant and an important feeding ground for populations of penguins, whales, seals and fish, shows that the centre of krill distribution has shifted towards the Antarctic continent by about 440 km (4° latitude) over the last four decades.[130] Concomitant to the decline in numerical densities of krill at the northern limit of their range and the increased concentrations over the Antarctic shelves, scientists have observed a change in the population structure, with the population being dominated by larger, older individuals. The warm, windy, cloudy weather and reduced sea ice brought about by a rapidly warming climate may hinder egg production and the survival of larval krill, whilst actually increasing the survival rate of adult krill.

A new model shows how a warming ocean has led to unprecedented marine biological changes at the global level over the last decade, and predicts that future increases in temperature will lead to major biological changes in the marine realm.[131] The model was cross-validated against 14 multi-decadal time series and sampled marine organisms from the continental shelf to the deep sea and across all latitudes. It underlines the sensitivity of the Arctic Ocean, where unprecedented melting may reorganise biological communities and suggests an increase in the geographical reach and severity of abrupt biological changes in a warming world.

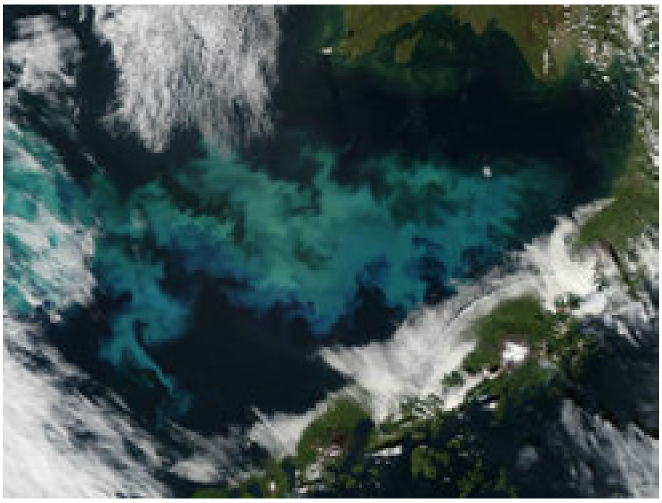
Another study examined the distribution and diversity of top predators in the Pacific in relation to climate change. Utilising a database of 4,300 electronic tags deployed on 23 marine species from the Tagging of Pacific Predators project and output from a global climate model up to 2100, the study predicted that there might be up to a 35% change in core habitat for some species, with some gaining core habitat and others losing it. Overall, it found a substantial northward displacement of biodiversity across the North Pacific.[132] For species that are already stressed from other pressures, the loss of preferred pelagic habitat and increased migration times could further exacerbate population declines or inhibit recovery. For example, blue whales showed a decrease in core habitat which might hinder their post-whaling recovery. For species with coastal breeding colonies and offshore feeding grounds that may move further from the existing colonies, there may be an associated energetic cost and reduced reproductive success.

As marine fishes and invertebrates respond to ocean warming through distribution shifts, generally to higher latitudes and deeper waters, so fisheries are being impacted. A 2013 study looked at the correlation between catches and sea surface temperature in 52 large marine ecosystems that make up the majority of the world's coastal and shelf areas. It showed that ocean warming has already affected global fisheries over the past four decades.[133] The study highlighted the immediate need to develop adaptation plans to minimise the effect of such warming on the economy and food security of coastal communities, particularly in tropical regions.

Climate change and the biological carbon pump

As explained earlier, the biological carbon pump plays a vital role in the net transfer of CO_2 from the atmosphere to the ocean, where a proportion of it may later be sequestered in the sediments. The efficiency of this process depends on phytoplankton physiology and community structure, which in turn are determined by the physical and chemical conditions of the surrounding ocean. Carbon and nutrient availability, temperature and mixing depth (and therefore light availability) are all factors that influence phytoplankton community structure and, as these factors change, so there will be changes in the phytoplankton communities. A 2018 review looked at global climate change and its effects on phytoplankton physiology and community structure. It notes a change in the strength of the biological pump in response to a changing climate. However, predicting the direction of such change—a strengthening or weakening over the next 100 years—is difficult owing to the complexity of the system.[134]

Alterations caused by global climate change on the oceanic carbonate system, including temperature, light and nutrient availability, will vary in different regions of the ocean. So too will the effects on phytoplankton, which may be synergistic or antagonistic. Studies undertaken in the Atlantic and the Pacific have found that warmer ocean temperatures limit how much organic carbon is being transported into the deep ocean.[135] The results suggest that in warmer water, dead phytoplankton and other organisms are more likely to degrade in the upper ocean before they can sink. This means that the carbon in their cells dissolves and may be more rapidly released and recycled, staying in the surface ocean where it can be more easily released back into the atmosphere. This could lead to an amplifying feedback loop with a slowing of the biological pump as global temperatures rise further.



Phytoplankton bloom viewed from space
© Jeff Schmaltz / NASA

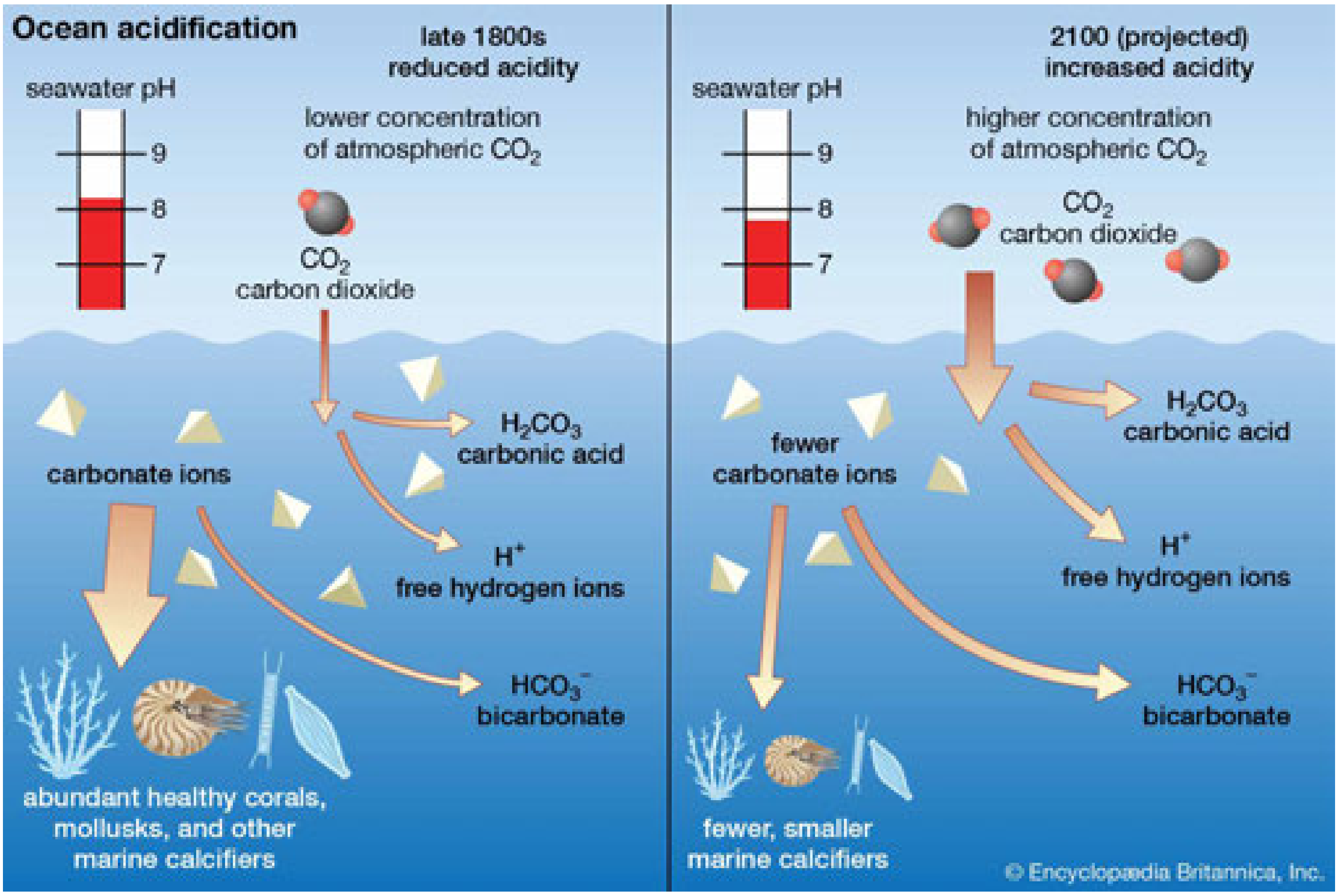
> **"Surface ocean acidity has already increased by around 30% since pre-industrial times, with recent changes occurring faster than at any time in at least the last 400 thousand years."**

Ocean acidification

The term ocean acidification describes the ongoing decrease in ocean pH caused by the ocean absorbing a proportion of the atmospheric CO_2 produced by the burning of fossil fuels. While this has reduced the speed with which CO_2 levels have risen in the atmosphere, and thus reduced climate change impacts, ocean acidification has the potential to cause widespread and profound impacts on marine ecosystems. Ocean acidification, like climate change, is a dire consequence of living in a high CO_2 world and for this reason, has been dubbed the 'evil twin of climate change'.[136]

Surface ocean acidity has already increased by around 30% since pre-industrial times, with recent changes occurring faster than at any time in at least the last 400 thousand years.[137] The average pH of ocean surface waters has already fallen by about 0.1 units, from about 8.2 to 8.1 since the beginning of the Industrial Revolution. This is very significant as the pH scale is like the Richter scale logarithmic, meaning a drop of just 0.1 pH units represents approximately a 30% increase in acidity.

Recently, researchers set out to reconstruct levels of ocean acidity and atmospheric CO_2 levels over the past 22 million years. They studied the fossils of tiny marine creatures that once lived near the ocean surface and analysed the chemistry of their shells to determine the acidity of the seawater in which they lived.[138] In the context of the future carbon emission scenarios recognised by the IPCC, the researchers found that, under a business-as-usual scenario, by 2100 the predicted ocean pH of less than 7.8 will be at a level not experienced since the Middle Miocene Climatic Optimum period (around 14 million years ago)—a time when global temperatures were around 3°C warmer than today.



By courtesy of Encyclopædia Britannica, Inc., copyright 2018; used with permission

The predicted change in basic ocean chemistry and the speed of that change is likely to have far-ranging impacts on marine species and ecosystems. Some species will migrate to less affected or unaffected areas, some will adapt and others will be driven to extinction.[139] Overall, these effects will alter food webs with the potential to impact ecosystem function.

Marine organisms that rely on dissolved carbonate to build their shells or external skeletons are among the ones who are at most risk from ocean acidification. These include calcareous plankton, sea butterflies, shellfish, sea urchins, crustaceans and corals.

But the detrimental impacts of ocean acidification extend well beyond those associated with secretion of calcium carbonate structures; other impacts include:[140]

→ **Reduced survival in the larval stages of marine species, including commercial fish and shellfish**

→ **Impaired development in invertebrates at fertilisation, egg and larval stages, settlement and reproduction**

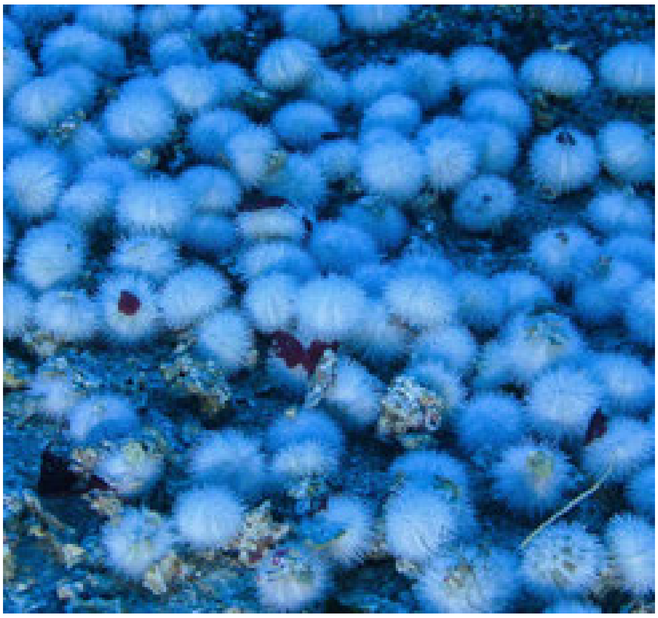
→ **Excessive CO_2 levels in the blood of fish and cephalopods which can cause toxicity to significantly reduce growth and fecundity in some species**

→ **Profound effects on the sensory perception of marine organisms, with highly variable responses based on species, life-stage, ecosystem and parental influence[141]**

→ **Deleterious impacts on the dispersal and settlement of larval fish[142]**

The polar oceans are especially vulnerable to the impacts of ocean acidification. Colder water is able to absorb higher amounts of carbon dioxide compared to warm water and is naturally less saturated with calcium carbonate, especially in its aragonite form. Additionally, melting sea ice is increasing the surface area through which carbon dioxide uptake can occur, whilst reducing salinity. This is a problem because dissolved salt helps buffer against the impact of acidification.

It was from samples of the pteropod *Limacina helicina Antarctica* —a species of sea butterfly that were extracted live from the Southern Ocean early in 2008— that scientists first discovered physical evidence of the effects of ocean acidification. When viewed under a scanning electron microscope, patches of weakness in the animals' usually smooth shells were visible to the scientists. This is the result of more acidic waters dissolving the aragonite shells.[143] This may render the pteropods more susceptible to predation and disease.[144]



Sea urchins in the Amazon Reef
© Greenpeace

In the Arctic, researchers have found that ocean acidification is being exacerbated further by the flow of Pacific Winter Water into the western Arctic Ocean enabled by the retreating summer sea ice.[145] As this mass of water moves, it absorbs additional carbon dioxide from decomposing organic matter in the water and sediments. This increases the water's overall acidity, such that more rapid acidification is occurring in the Arctic Ocean than in either the Pacific or Atlantic. Indeed, the western Arctic Ocean is now considered the first open-ocean region with large-scale expansion of 'acidified' water directly observed in the upper water column.

A comparison of the vulnerability of the polar oceans to anthropogenic acidification suggests that several factors, including lower alkalinity, enhanced warming, and nutrient limitation, render the Arctic more vulnerable.[146] In the Antarctic, the seasonal changes are more pronounced; in summer, melting glacial and sea ice results in important iron inputs that lead to enhanced summer production and CO_2 removal, allowing for some mitigation of acidification.

Ocean acidification is also of particular concern in regions like the California coast, where seasonal upwelling occurs.[147] Here, strong winds cause surface waters to move away from the shoreline causing colder, nutrient-rich, deeper water to rise from below. This water is also rich in dissolved CO_2 and has a naturally lower pH compared to the water it replaces. Upwelling regions are biologically important because the nutrient-rich waters rising to the surface support diverse populations of marine life.

Deoxygenation

Ocean deoxygenation refers to the loss of oxygen from the oceans due to climate change. Marine creatures, such as fish and crustaceans require higher oxygen levels and are highly vulnerable to oxygen declines, whereas others such as jellyfish and squid may be more tolerant.[148]

Oxygen minimum zones (OMZs) are 'pools' of subsurface water where oxygen concentrations fall from the normal range for subsurface of 4–6 mg/l to below 2 mg/l. They occur worldwide at depths of about 200 to 1,500 m from biological processes that lower oxygen concentration and physical processes that restrict water mixing between the OMZ and surrounding areas. Often located in the eastern boundary of an ocean basin, OMZs are expanding as a result of climate change.[149] The location of these zones is due to a combination of factors. Firstly, as ocean waters warm, the water holds less oxygen. Secondly, increased surface temperatures lead to increased stratification (and less mixing). Finally, increased CO_2 at the surface or nutrients from coastal run-off leads to increased phytoplankton production. As the phytoplankton die and sink there is a commensurate increase in bacterial activity and this leads to lower levels of oxygen in the OMZ.

The expansion and shoaling (rising of the upper boundary) of ocean OMZs experienced over the last 50 years is predicted to continue alongside increasing global temperatures. This is likely to have major and far-reaching consequences. The multiple effects include altered microbial processes that produce and consume key nutrients and gases, changes in predator-prey dynamics, and shifts in the abundance and accessibility of commercially fished species.[150] As with other climate-related changes, there will be a few winners and many losers.

For example, an interdisciplinary collaboration between oceanographers, fisheries, biologists and animal taggers has shown how the expansion of OMZs may have reduced the available habitat for tropical pelagic fish such as tuna and billfish by ~15% between 1960 and 2010.[151] The researchers found that shoaling of OMZs concentrates both predators and prey in progressively shallower surface areas which could lead to overly optimistic abundance estimates derived from surface fishing gear. Blue marlin (*Makaira nigricans*) may dive as deep as 800 m if there is plenty of oxygen available but if this is limited then that can constrain their dives to around 100 m deep, hitting the boundary of the deeper OMZ. Changes in behaviour can mean that some commercially exploited species, such as sharks, are more available to fishermen as they are found higher in the water column due to avoiding OMZs.

Other ecologically important species that are likely to be affected by the expansion and shoaling of OMZs include krill and myctophid fish, which carry out diel vertical migrations from the upper regions of OMZs to epipelagic waters above. The vertical compression-suitable habitat for certain species that require well-oxygenated waters can alter predator-prey relationships by concentrating prey in the near surface waters.[152]

Marlin
© Paul Hilton / Greenpeace

> "The polar oceans are responsible for absorbing more than 75% of the total heat absorbed by our oceans, despite only accounting for about 20% of the total surface of the oceans."

The polar oceans —feeling the heat

The polar oceans are crucial to the functioning of the Earth system. They are the engine of the thermohaline ocean conveyor, driving global ocean circulation and moving heat, oxygen, carbon, dissolved minerals and organic matter around our planet. Nutrients exported from the Southern Ocean sustain a significant proportion of global ocean primary production outside the Southern Ocean, underpinning food webs around the globe.[153, 154]

The polar oceans are also the biggest contributors to the global marine heatsink. They are responsible for absorbing more than 75% of the total heat absorbed by our oceans, despite only accounting for about 20% of the total surface of the oceans. Additionally, the polar oceans absorb much of the human-made CO_2 that our seas remove from our atmosphere, with the Southern Ocean alone soaking up around 40% of all the carbon our oceans extract from the air. Home to many extraordinary species of marine life, all of which have evolved to survive the demanding conditions, the polar regions are the fastest changing on Earth and among the most vulnerable.[155]

The differing impacts of climate change on the polar oceans

Some of the impacts on the polar oceans resulting from climate change and ocean acidification are described in earlier sections of this report. These include the melting of glaciers and ice sheets, the changes in the distribution of organisms in the polar regions as sea temperatures rise and the dissolution of the calcareous shells of pteropods as the polar waters become more acidic. While the polar oceans share many attributes, there are significant differences—the most obvious being that the Arctic Ocean is near-surrounded by land compared with the Antarctic continent, which is surrounded by the Southern Ocean. Differences in size, age, isolation, depth, oceanography and biology mean that there are and will be differences in climate change and ocean acidification impacts on the two regions. For example, lower freshwater input and higher buffering in Southern Ocean surface waters means that the effects of ocean acidification on the Antarctic are expected later than in the Arctic Ocean, reaching critical aragonite saturation concentrations by 2030. Yet some Arctic waters are projected to become chemically

The Arctic
© Markus Mauthe / Greenpeace

The Antarctic
© Daniel Beltrá / Greenpeace

> **"Summer temperatures in the Arctic Ocean are now 2–3°C warmer than the 1982–2010 mean and there has been a corresponding reduction in summer sea ice extent of nearly 50% from the late 1970s to 2017."**

corrosive to aragonite and drop below the threshold within a decade. This is under all emission scenarios considered by the IPCC.[156, 157]

A 2014 review of how increased climate change will impact Southern Ocean ecosystems concluded that there will be an overall warming and freshening of the present-day system, including a strengthening of westerly winds, a potential poleward movement of those winds and the frontal systems, and an increase in eddy activity.[158] These factors will affect the extent of the sea ice in different parts of the Southern Ocean—noting that due to a complex interplay of factors, there has been an overall increase in the amount of Antarctic sea ice in recent decades despite the warming. These factors will also affect the timing and magnitude of primary production, with knock-on effects on the many species that are dependent on the phytoplankton spring bloom. How different taxa of organisms will be able to withstand or adapt to these changes will depend on their physiological adaptability and their ability to move to areas where they can survive. While the overall consequences of the ongoing environmental changes are not well understood, they are expected to go beyond shifts in species ranges and possibly result in novel functional organisation and dynamics of Antarctic and Southern Ocean food webs and reduced biodiversity.

The Arctic is responding to climate change more rapidly, and likely more severely than anywhere else on Earth. Polar seas are particularly vulnerable to climate change due to their sensitivity to sea-ice retreat.[159] Summer temperatures in the Arctic Ocean are now 2–3°C warmer than the 1982–2010 mean and there has been a corresponding reduction in summer sea ice extent of nearly 50% from the late 1970s to 2017.[160] Declines in the extent and thickness of sea ice are exacerbated by a feedback loop, whereby a smaller area of ice decreases the global albedo (the amount of light reflected) and so less heat is reflected back from the surface. This leads to further thawing of the permafrost and thinner, less compact ice, which is more vulnerable to breaking up from strong winds. Overall, there has been a fundamental shift in the Arctic sea ice regime, from one which was dominated by thick multi-year ice to one controlled by thinner, more dynamic, first year ice.

The Arctic Ocean is changing in other ways too. Analysing data obtained from tethered moorings, researchers have found that warm water from the Atlantic has been penetrating the barrier into Arctic waters, causing the ice to melt from below.[161] Normally, the warm Atlantic water is separated from melting ice because of the halocline layer, a barrier that exists between deep salty water and fresher water closer to the surface. This 'Atlantification' of the Eurasian Basin of the Arctic Ocean helps explain the rapid decimation of Arctic ice and is also likely to cause substantial biogeochemical and geophysical changes which will affect marine life of the region. For example, phytoplankton blooms may occur in new locations.

The changes described above, together with other issues such as a reduced nutrient flux from increased stratification caused by increased freshwater entering the Arctic Ocean, will all cause upheavals in Arctic marine ecosystems. As climate change can affect marine organisms through many different interlinked processes, there are likely to be many unanticipated changes.[162] Within food webs, climate change has affected primary productivity and the distribution, abundance and body condition of top predators. One of the most significant changes has been a shift from polar to temperate primary production patterns, with an increase of 30% in annual net primary production over the Arctic Ocean between 1998 and 2012.[163, 164]

Changes in primary productivity and planktonic communities can impact top predators and many iconic marine species. For example, little auks (*Alle alle*), otherwise known as dovekie birds, have been found making longer foraging trips in areas of the Atlantic where their preferred copepod prey items, the lipid-rich *Calanus glacialis* and *C. hyperboreus*, have been replaced by a smaller, less nutritious copepod species (*Calanus finmarchicus*) that is more abundant in waters warmed by the increased inflow of waters derived in the Atlantic.[165] Changes in foraging behaviour, particularly where individuals have to make longer trips and expend more energy, may have population-level impacts on species that are yet to be fully understood.

A flock of dovekies

© Bernd Röemmelt / Greenpeace

Climate change impacts on ice-dependent marine mammals

The iconic Arctic marine mammals most closely associated with the sea ice are the narwhal, beluga, bowhead whale, ice-dependent seals (for example: the ringed, bearded, spotted, ribbon, harp and hooded seals), the walrus and the polar bear. A 2015 study investigated data relating to all populations of these Arctic marine mammals and the availability of suitable sea ice habitat for the circumpolar region, except the central Arctic basin.[166] The authors found that for many sub-populations, the population data are poor. These findings are not surprising given the wide distribution and cryptic behaviour of many species and the challenging logistics of surveying in the Arctic environment. This lack of baseline data makes it difficult to determine population trends. The researchers quantified loss of sea ice habitat based on timing of the seasonal change between winter and summer sea ice conditions. They found significant trends in the dates of spring sea ice retreat and autumn sea ice advance for the period between 1979 and 2013. For all but one of the regions studied, the Bering Sea being the exception, researchers found profound changes to sea ice. The period of reduced summer ice was extended by 5–10 weeks and by more than 20 weeks in the Russian Barents Sea. Responses by Arctic marine mammals to these climate-related changes in sea ice will vary and may even be positive in the short term for some species if ecosystem productivity increases.

For the ice-dependent (or pagophilic) seals, the timing of sea ice break-up is vital because they need sufficient time to wean their pups prior to it happening. Any shortening of the period of suitable pupping habitat can reduce pup survival rates. Ringed seals can only make their lairs in specific conditions in ice and snow. Pacific walrus forage in shallow waters using ice floes to rest. In recent years, as the summer ice retreats, walrus have been forming large colonies onshore earlier in the year than previously recorded. Potential overcrowding is a concern as it can lead to stampedes in which individuals are crushed and die.[167]

> "As the summer ice retreats, walrus have been forming large colonies onshore earlier in the year than previously recorded. Potential overcrowding is a concern as it can lead to stampedes in which individuals are crushed and die."

Walrus on an ice floe in the Arctic
© Denis Sinyakov / Greenpeace

Polar bears in the Arctic Ocean
© Nick Cobbing / Greenpeace

The polar bear, which is listed as vulnerable on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species, is especially dependent on sea ice, using it as a platform from which to hunt, find a mate and rear young. In short, the ice is a platform for the bear's entire life cycle.[168] To survive the extreme conditions of their Arctic home, polar bears have high energy demands which are satisfied by consumption of high fat prey such as seals which are relatively easy for the bears to find on sea ice.[169] However, changing sea ice conditions are causing bears to invest more energy into finding sufficient prey. The increased investment is affecting this species' finely tuned energy balance with population-level impacts. For example, retreating ice in the Beaufort and Chukchi Seas is forcing bears to make marathon journeys, increasing mortality of polar bear cubs and putting immense stress on adults. One female polar bear is known to have swum for a record-breaking nine days straight, traversing 426 miles (687 km) of water in search of prey.[170] Climate change and reductions in summer sea ice are thought by scientists to be likely drivers for the increasing numbers of polar bears at four study sites on the west coast of Spitsbergen (Svalbard) and a site in east Greenland. In these places, some bears appear to be adapting their feeding behaviour to changing environmental conditions and opportunistically predating on nests of barnacle geese, common eiders and glaucous gulls. In years when the bears arrive before the eggs have hatched, as many as 90% of nests may have been predated.[171] The long-term effects of this change in feeding behaviour are not fully understood, but the example illustrates a possible cascading ecosystem effect from climate change.

> "One female polar bear is known to have swum for a record-breaking nine days straight, traversing 426 miles (687 km) of water, due to retreating sea ice.

Seal pup in Svalbard
© Nick Cobbing / Greenpeace

Coral reefs

Climate change and the associated threat of ocean acidification pose the greatest global threat to coral reef ecosystems throughout the ocean. Negative impacts occur at the individual through to the ecosystem level as the survival, recruitment, growth and reproduction of corals and associated reef organisms are reduced. The threat is serious, and in some cases we may have already passed the point of no return, with scientists warning that even lower greenhouse gas emission scenarios (such as RCP 4.5) are likely to drive the elimination of most warm-water coral reefs by 2040–2050.[172] Urgent protection is needed for these particularly fragile ecosystems.

Warm water corals

Warm water corals and algae have a symbiotic relationship which goes back at least 210 million years.[173] This symbiotic relationship is mutually beneficial for both organisms. The coral provides the algae (*zooxanthellae*) with shelter and the compounds they need for photosynthesis. The algae produces oxygen, helping eliminate wastes and supplying the coral polyps with food in the form of sugars, glycerol, lipids and amino acids via photosynthesis.[174] Coral bleaching occurs when stressed corals expel the tiny algae living in their tissues, leaving behind a stark white skeleton. The loss of their symbionts leaves the corals vulnerable to death and disease, and less able to compete with other benthic organisms. In some parts of the world, there has been a catastrophic loss of corals over the last 30 years.[175, 176]

As sea temperatures rise, severe coral bleaching events of warm water coral reefs are becoming more frequent. An analysis of a dataset of coral bleaching events from 1980 to 2016 for 100 coral reefs in 54 countries found that, across the globe, the risk of bleaching has increased at a rate of 4% per year, with 8% of reefs being affected by bleaching per year in the 1980s and 31% being affected in 2016.[177]

Another study looked at the global coral bleaching event of 2014–2017 and how this compared with bleaching events of the previous three decades. It found that the extent of corals experiencing bleaching increased over the study period and accelerated during the last decade.[178] More than three times as many reefs were exposed to bleaching-level heat stress during the 2014–2017 global bleaching event than were exposed in the 1998 global bleaching. The researchers found that this increase is the result of longer stress events rather than an increase in the peak stress intensity. In the past, when bleaching events were relatively rare, coral reefs had a window of time in which they could recover. However, now that the average interval between bleaching events is less than half of what it was before, the window is becoming too short for reefs to fully recover between bouts of bleaching.

A key factor in determining the recovery of a coral reef is the number of coral larvae that are settling on the reef and replenishing it. Unfortunately, 'dead corals do not make babies'.[179] Research has revealed that the number of new corals settling on the Great Barrier Reef declined by 89% compared to historical levels, following the unprecedented loss of adult corals from global warming in 2016 and 2017.[180] The biggest decline in replenishment (93% on previous years) occurred in the dominant branching coral, Acropora, species that are important in giving the reef structure.

Healthy coral in the Great Barrier Reef
© Darren Jew / Greenpeace

Bleached coral in the Great Barrier Reef
© Dean Miller / Greenpeace

Coral reef in the Andaman Sea, Thailand
© Sirachai Arunrugstichai / Greenpeace

Cold water corals

While some corals have evolved symbiotic relationships with algae and are restricted to warm, shallow waters where photosynthesis can occur, there are other species of coral that inhabit cold, deep waters. Found on continental shelves, slopes, canyons, seamounts and ridge systems throughout the ocean, in waters ranging from 40 m to 2,000 m deep, cold-water corals get nutrition from feeding on the microscopic organisms that descend from above and flow in ocean currents. They are important 'ecosystem engineers', providing three-dimensional habitats in the form of 'coral gardens'. Frequently structured by bamboo or gorgonian corals, these large, deep-water framework reefs are usually constructed by one or two small groups of scleractinian corals.[181] These coral habitats are home to reams of other species, with suspension feeders like sponges, hydrozoans and bryozoans often found in abundance. Our knowledge of cold-water corals and their extent in the deep ocean has increased over the last few decades, but our understanding of how these critically important reefs are likely to respond to changing environmental conditions, especially steadily warming temperatures, is limited. A study which looked at data from the geological record suggests that food supply may be the most prominent key driver in the demise and re-establishment of cold-water corals.[182] Food supply appears to be controlled by a complex interplay of surface-ocean productivity and bottom-water hydrodynamics, both of which may be affected by rising ocean temperatures.

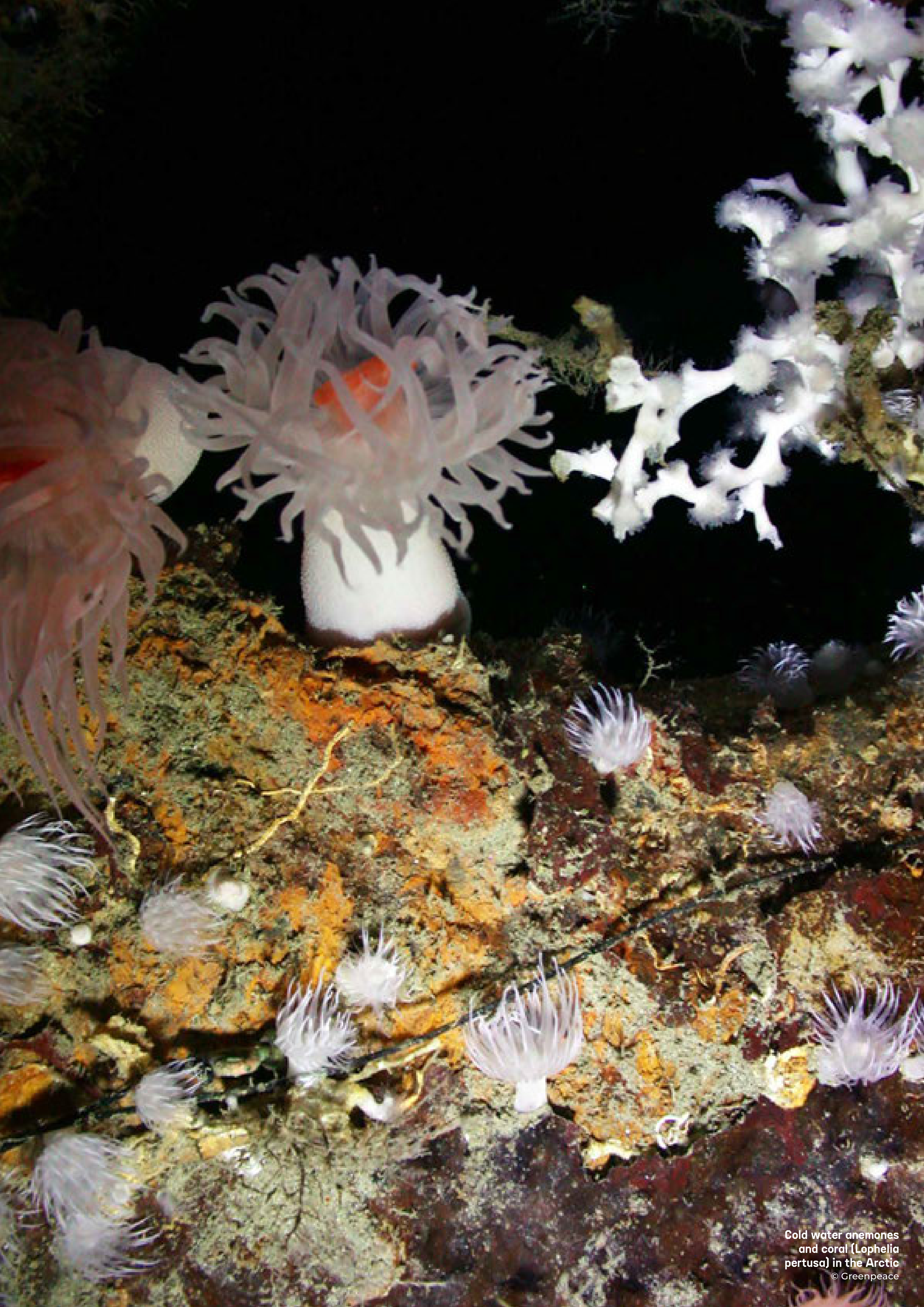
Both warm water and cold water coral reefs are sensitive to the effects of ocean acidification (see page 34), with cold water corals identified as especially vulnerable. As ever, different species are likely to respond differently. Laboratory experiments have shown that some species of corals and calcifying algae do not have the capacity to acclimate to ocean acidification, while two species of coral were resistant from the start.[183] The study suggests the composition and function of future reefs, if they can survive climate change, will be very different from the reefs we have today.[184]

Recent research indicates that ocean acidification could threaten around 70% of cold water coral living below 1,500 m in the North Atlantic by 2050.[185] These animals build their fragile external skeletons with aragonite but are only able to do so when the seawater is sufficiently saturated with it, namely above the 'aragonite saturation horizon' (ASH). Below this boundary the seawater is under-saturated, meaning that it can dissolve and weaken hard corals. Using observational data from 2002–2016, researchers have found that the depth of the ASH is rising in some parts of the North Atlantic. For example, in the Irminger Sea off the southern coast of Iceland it has risen by 10–15 m per year.[186] As the ASH rises, so the proportion of corals that will be exposed to corrosion will increase. Looking at future emissions scenarios for CO_2, it has been concluded that within three decades, North Atlantic cold-water corals could become severely threatened.

> **"The future survival and condition of the world's coral reefs and the multitude of benefits they provide to humanity depends entirely on the trajectory of global emissions and on our capacity to build resilience through removing and minimising multiple stressors."**

While many studies are limited to investigating a single stressor, there is a study on the interactive effects of ocean acidification and warming on the cold water coral *Lophelia pertusa*.[187] Researchers have found that under certain conditions, the negative effects of ocean acidification may be counteracted by increased water temperatures. However, they suspect *Lophelia pertusa* will only benefit from rising temperatures as long as they stay within the limits that this species is currently experiencing in its distributional range. Many *Lophelia pertusa* reefs are already at their temperature limit and, if temperatures continue to rise, the compensatory effect observed by the research team could turn negative, amplifying the effect of ocean acidification.[188]

The future survival and condition of the world's coral reefs and the multitude of goods and ecosystem services they provide to humanity—food, income, recreation, protection from storm waves and coastal erosion, cultural significance and more—depends entirely on the trajectory of global emissions and on our capacity to build resilience through removing and minimising multiple stressors.



Cold water anemones and coral (Lophelia pertusa) in the Arctic
© Greenpeace

Coastal development in Spain
© Pedro Armestre / Greenpeace

THE IMPACT OF OTHER THREATS ON THE SEQUESTRATION AND STORAGE OF OCEAN CARBON

We have explored how vegetated marine coastal habitats like mangroves, salt marshes and seagrass meadows are important sinks of blue carbon, yet they rank amongst the most threatened marine ecosystems in the world. Since the 1940s, coastal eutrophication, reclamation, engineering and urbanisation has led to the loss of a substantial fraction of the earth's blue carbon sinks, with other human activities at sea, such as bottom trawling and deep sea mining, disturbing the sediment and disrupting carbon sequestration.

Destruction of coastal habitats

Nearly 2.4 billion people live within 100 km (60 miles) of the coast, putting enormous stress on the resources and services provided by the marine and coastal environment on which they depend.[189] In 2017, people living in coastal communities represented 37% of the global population, with coastal population growth and urbanisation rates outstripping the demographic development inland.[190]

This coastal urbanisation is having an alarming impact on blue carbon ecosystems. For example, on average globally, mangroves are being lost at a rate of 1–2% per year, with many of those that remain in a degraded condition. Over the past 50 years, 30–50% of mangrove forests have been lost and, if destruction continues at the current rate, there could be no mangroves left by the turn of the next century.[191] Destruction rates are highest in developing countries, where more than 90% of the mangrove forests grow. As the destruction of mangroves continues, so does the important capability of mangrove forests to act as both a carbon source and sink. A 2016 report estimated that aquaculture is accountable for the loss of a significant amount of mangrove habitat globally, with 1.4 million hectares lost to shrimp farming and 0.49 million to other forms of coastal aquaculture.[192] This is disturbing given the role that mangrove habitats serve in mitigating the effects of anthropogenic CO_2 emissions.

Furthermore, despite the important role of seagrass meadows for the health of the planet (see page 16), they too are threatened globally, with evidence indicating accelerating rates of loss and degradation.[193] It has been reported that a seagrass ecosystem that was disturbed 50 years ago showed a 72% decline in carbon stocks[194] and seagrass areas that had regenerated after a period of disturbance had a level of carbon that was 35% lower than undisturbed areas. Widespread disturbance of carbon sequestered in sediment can reduce sequestration rates and unlock carbon that has been stored for millennia.

Similarly, salt marshes that in the past have been regarded by some as useless wastelands have also been lost. A common practice is to reclaim salt marshes for agriculture, while other areas have been turned into waste dumps or been encroached upon by urban development.[195] In Europe for example, it has been estimated that over 50% of salt marsh and seagrass areas have been lost to coastal development. Dredged, drained, ditched, diked, grazed and harvested, people have altered the hydrology and ecology of salt marsh habitats the world over.[196] Pollution from organic, inorganic and toxic substances discharged into estuaries, the spraying of insecticides for mosquito control and the introduction of non-native species have also taken their toll. Destroying habitats like tidal salt marshes and mangroves to build roads and pavements prevents these habitats from natural expansion and regeneration.

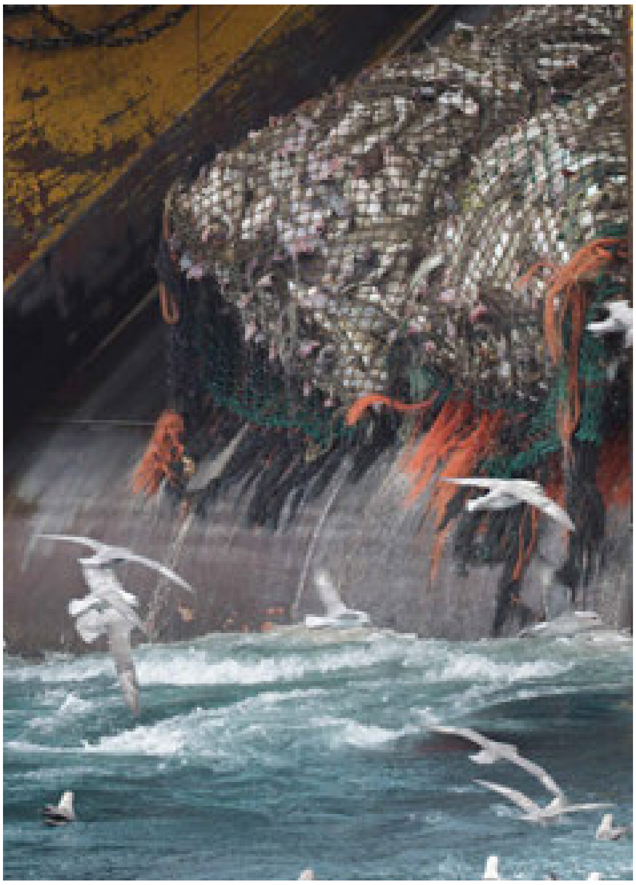
Overfishing and destructive fishing practices

While we do not as yet understand the full extent of the complex interactions between fish, other marine vertebrates and biogeochemical cycling, including carbon cycling and sequestration, there is increasing evidence, especially given their large biomass, that fish play a significant role. For this reason, fishing will inevitably have consequences for these processes, though currently it is not possible to quantify their full scale.[197]

One example of the detrimental impact of fishing to carbon sequestration can be found in the salt marshes of Cape Cod in the U.S. Here, recreational overharvesting of predatory fish and crabs has triggered marsh die-off and major erosion through a trophic cascade and has contributed to the reduced carbon storage capacity of the ecosystem by 17,000 tonnes of carbon annually.[198]

Perhaps unsurprisingly, the large biomass of unexploited mesopelagic fish in the deep ocean, which plays an important part in carbon sequestration, has elicited interest from the fishing industry, with Pakistan and Norway both putting feelers out as to possible future exploitation.[199, 200, 201] However, as many experts have warned, fishing for mesopelagic species needs to be sustainable and should not compromise the oceans' ability to sequester carbon. As Professor Carlos Duarte writes, 'Because the stock is much larger it means this layer must play a more significant role in the functioning of the ocean and affecting the flow of carbon and oxygen in the ocean.'[202]

Additionally, bottom trawling along continental slopes has a major impact on deep sea ecosystems, causing their degradation and depleting populations of organisms which make their home in the sediments of the ocean floor. Some scientists have compared the cumulative impacts of trawling in deep sea sedimentary ecosystems to the catastrophic impacts of accelerating, human-caused soil erosion on land. Deep sea fisheries employ heavy trawling gear that is highly destructive, reducing benthic biodiversity—especially the number of suspension feeders—and resuspending sediments which release buried carbon. Deep sea trawling occurs over large areas and may therefore disrupt deep sea ecosystem functions, impacting carbon cycling and other important biogeochemical cycles at a global scale.[203]



Bottom trawler in the Barents Sea
© Nick Cobbing / Greenpeace

The Lost City in the Atlantic Ocean—a hydrothermal field under threat from deep sea mining © NOAA / OAR / OER

Deep sea mining —a serious threat

Deep sea mining is an emerging threat to hydrothermal vents, abyssal plains and seamounts on the ocean floor. Seeking to extract the valuable metals derived from sulphides, cobalt and polymetallic nodules, mining further impacts ecosystems that are already suffering from ocean warming, oxygen loss, increasing acidity and altered food supplies[204]—drivers which likely compromise the ability of marine life to recover from mining disturbance.[205]

Furthermore, the removal of animals and the disturbance of microbes by deep sea mining, combined with changing temperature and oxygen depletion caused by sediment plumes, could alter midwater carbon transport processes. This could in turn affect global carbon cycling and the sequestration of carbon in the deep seabed. Research suggests that hydrothermal vents, one of the focuses for the deep sea mining industry, could be globally important for distributing organic carbon to deep sea sediments.[206] As well as disrupting these important processes, the physical disturbance of the seabed by mining operations could re-suspend stored carbon buried in the sediment and therefore risks affecting the longevity and rate of carbon burial in deep sea sediments.[207]

A local resident watches high waves surge past the sea wall and into his family's property. Tarawa Island, Kiribati, Pacific Ocean

© Jeremy Sutton-Hibbert / Greenpeace

Cumulative impacts and synergistic effects

The world's oceans are now affected by multiple, unprecedented anthropogenic stressors which do not operate in isolation.[208] The impacts of increasing CO_2 emissions from the burning of fossil fuels, including ocean warming, acidification and deoxygenation, all potentially interact with each other and with other human impacts, including overfishing, pollution and the establishment of invasive species.[209] Predicting the cumulative and interactive effects of these stressors and the potential for resistance or resilience of individual organisms or ecological communities is highly complex, especially as effects may be additive, synergistic or antagonistic.[210]

Synergistic effects occur when the combined impact of two or more stressors on an ecological response (e.g. diversity, productivity, abundance, survival, growth, reproduction) is greater than the sum of impacts from individual stressors. Such synergistic effects occur because a change caused at the physiological or ecological level by one stressor increases the severity or occurrence of effects of a second stressor. How organisms respond to multiple stressors will depend on their magnitude and the synergistic effects most common when stressors occur close together in time.[211] The possibility that multiple co-occurring stressors may have synergistic effects is of particular concern because they could provoke unpredictable 'ecological surprises' and cascading impacts that could accelerate biodiversity loss and impair the functioning of ecosystems.[212]

Scientists have found that climate change and overfishing are likely responsible for a rapid restructuring of a highly productive marine ecosystem in the North Sea. Others have demonstrated how the synergistic impacts between ocean acidification, global warming, and expanding deoxygenation will compress the habitable depth range of the jumbo squid (*Dosidicus gigas*), a top predator in the Eastern Pacific.[213, 214] These examples of detrimental synergistic effects show that concern is not misplaced, with more being added from around the world. For instance, the British Antarctic Survey is currently running a project to investigate the synergistic impact of nanoplastic and ocean acidification on marine ecosystems in the Southern Ocean.[215]

Climate change and ocean acidification act as threat multipliers by combining with other anthropogenic impacts causing serious cumulative effects, which are diverse, widespread and profound, not only affecting the ecology of the ocean, but also producing significant socioeconomic consequences.[216] Climate change and ocean acidification are already exacerbating challenges relating to food security, livelihoods and the development of communities, so undermining the ability of states, in particular many of the world's least developed countries and SIDs, to achieve sustainable development.[217]

Green turtle in the Sargasso Sea
© Shane Gross / Greenpeace

HOW OCEAN SANCTUARIES CAN MITIGATE AND PROMOTE ADAPTATION TO CLIMATE CHANGE

The pervasive threats to ocean life associated with burning fossil fuels must be addressed at the source by drastically cutting emissions of CO_2. However, this course of action alone will not be sufficient to avert further stresses being exerted on marine life.[218] Other measures need to be implemented to safeguard marine life, boost ecosystem resilience and help maintain vital ecosystem functions that provide vital services to us all.

One of the key tools available is the establishment of effective networks of fully protected marine reserves—known as ocean sanctuaries. A well-managed network of ocean sanctuaries can yield multiple benefits at all scales, from the local to the global. Sanctuaries can help species, ecosystems and the people who depend on them to adapt to the impacts of anthropogenic CO_2 and mitigate climate change by promoting carbon sequestration and storage, as well as act as buffer zones against environmental uncertainty.[219]

While partially-protected marine protected areas (MPAs) may generate benefits in certain contexts, scientific evidence consistently shows that the greatest ecological benefits from protection are derived from strongly or fully protected areas such as ocean sanctuaries.[220,221] By excluding extractive activities and removing or minimising other human pressures, species can maintain or recover abundance, biomass and diversity.[222] For example, a meta-analysis of scientific studies showed that the biomass of fish assemblages is, on average, 670% greater within ocean sanctuaries (i.e. fully protected areas) than in unprotected areas, and 343% greater than in partially-protected MPAs. Fish biomass is a powerful metric to use in assessing MPA success because it provides a strong indicator of the health of fish assemblages and thus ecosystem health.[223, 224] The elimination of extractive and damaging activities protects marine life from the sea surface to the seabed, preserving important ecological and biogeochemical links, ensuring the protection of the whole ecosystem and the safeguarding of related ecosystem processes.[225]

Within ocean sanctuaries, populations may grow, their age structure change and their reproductive output increase.[226, 227] These factors confer resilience, larger populations and higher reproductive outputs which buffer against decline, meaning that species are less likely to become extinct at local, regional or global scales.

Examples of the resilience conferred from protection are beginning to accrue. For example, corals in the Line Islands affected by the strong 1997–1998 El Niño recovered in fully protected reefs within a decade, whereas they did not in unprotected islands.[228] In Baja California, Mexico, a mass mortality event caused by climate-driven oxygen depletion affected commercially important pink abalone (*Haliotis corrugata*) populations, but they replenished faster within ocean sanctuaries because of the large body size and high egg production of the protected adults.[229] Moreover, this benefit extended to adjacent unprotected areas through larval spillover across the edges of the reserves.

Increases in population size and the broadening of the selective environment within ocean sanctuaries may lead to associated increases in genetic diversity. The adaptive capacity of a species is related to its genetic diversity and the standing genetic variation within a population (as compared with new mutations). This may determine how quickly the evolution needed for it to adapt or avoid extinction in a rapidly changing environment occurs.[230]

> "Fish biomass is, on average, **670%** greater within ocean sanctuaries (i.e. fully protected areas) than in unprotected areas, and **343%** greater than in partially-protected areas."

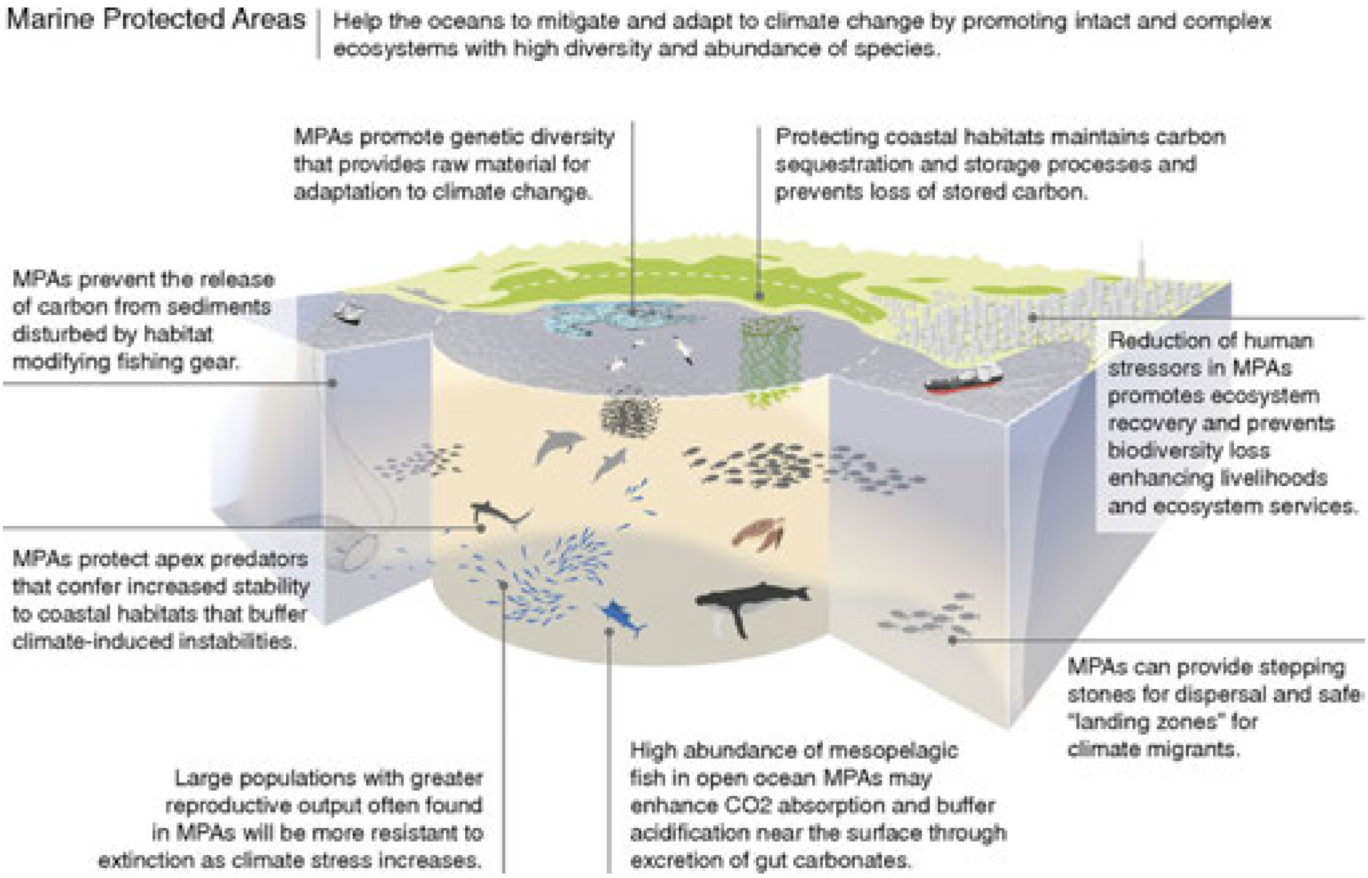
Networks of ocean sanctuaries may help accommodate shifts in the distribution of species caused by changes in the marine environment. They can provide stepping stones as species disperse, ‘safe’ areas for species to colonise, and possible refugia for those species that are unable to move.[231, 232, 233] Part of the rationale behind the establishment of the Ross Sea MPA is that as an area most likely to maintain stable sea ice, it will serve as a climate refugium for ice-dependent species.[234]

Protecting bony fish and especially the mesopelagic fish inhabiting open ocean areas may enhance CO_2 absorption and buffer against ocean acidification near the surface through the excretion of gut carbonates (see page 21).

Designing networks of sanctuaries to protect apex predators will ensure that they can maintain their roles in shaping and maintaining ocean ecosystems.[235] Researchers surveying sharks at Ashmore Reef in Western Australia found that after eight years of strict enforcement of a no-take ocean sanctuary, there was a shift in the assemblage of sharks to greater proportions of apex species (from 7.1% to 11.9%) and reef sharks (from 28.6% to 57.6%), and a decrease in the proportional abundance of lower trophic level species (from 64.3% to 30.5%).[236]

> **"Protecting bony fish and especially the mesopelagic fish inhabiting open ocean areas may enhance CO_2 absorption and buffer against ocean acidification near the surface."**

As well as dampening explosive prey growth and helping maintain ecosystem stability, predators can help prevent disease outbreaks. This is important considering that infectious diseases can decimate populations of marine organisms and are increasing among some taxa due to global change and the increasing pressures that humans are placing on marine environments.[237, 238] For example, the establishment of ocean sanctuaries in the Channel Islands of southern California led to increases in the size and abundance of spiny lobsters (*Panulirus interruptus*) which preyed upon sea urchins, leading to a decline the urchin population. A consequence of this was a lowered frequency of epidemics of sea urchin wasting disease as the disease was less able to spread.[239]



Eight illustrative pathways by which MPAs can mitigate and promote adaptation to the effects of climate change in the oceans. Source: Roberts C.M. et al. (2017)

Spiny lobster
© Gavin Parsons / Greenpeace

> "Strictly protected ocean sanctuaries are considered essential for climate change resilience and will be necessary as scientific reference sites to understand climate change effects."

Establishing strongly or fully protected ocean sanctuaries to conserve blue carbon ecosystems should be considered an urgent priority. Furthermore, fully protected ocean sanctuaries that prohibit destructive activities such as bottom trawling and deep sea mining will prevent the loss of stored organic carbon through disturbance. This may further promote carbon uptake by seabed ecosystems, allowing the recovery of various species important in carbon cycling processes.

Ocean sanctuaries can also serve as a source of baseline data by acting as control areas, determining the effects of human activities taking place beyond the protected areas' boundaries, and as important climate reference areas. Taking the above into account, the establishment of networks of fully and strongly protected ocean sanctuaries provides a viable, low-tech and cost-effective adaption strategy for 'future-proofing' our oceans in the face of massive environmental change. This would make a significant contribution to the pledges made by countries, such as under the Paris Agreement, to conserve ocean biodiversity and bolster ocean resilience.[240]

However, until recently, governments have not directly considered climate change and ocean acidification in the design, management or monitoring of ocean sanctuaries or sanctuary networks. But this is beginning to change. A 2016 study shows that strictly protected ocean sanctuaries are considered essential for climate change resilience and will be necessary as scientific reference sites to understand climate change effects. This shows that strictly protected sanctuaries managed at an ecosystem level are the best option for an uncertain future.[241]

Crucially, how effective ocean sanctuaries will be in delivering their objectives, including the increased sequestration and storage of blue carbon, depends on the levels of compliance and enforcement. Enforcement which needs to be adequately financed and resourced.[242] Community-based approaches and effective stakeholder participation can help, ensuring that designations of such areas meet their objectives.[243] The feasibility of ensuring that remote and large-scale marine reserves in the high seas are enforceable has recently been greatly enhanced by the development of new technologies, including satellite imaging, remote sensing and drones.[244]

In summary, the benefits, opportunities and advantages of well-established and managed ocean sanctuaries are proven and documented to grow over time and are an essential component of the ecosystem-based management portfolio that will deliver healthy and sustainably managed oceans. Given the severity of the various ocean stressors and the need for urgent action, it is vital that the best available science is used to expedite the establishment of ocean sanctuaries globally.

How much should be protected?

The value of MPAs and, in particular, fully-protected ocean sanctuaries, as a key tool in protecting habitats and species, rebuilding ocean biodiversity, helping ocean ecosystems recover and maintaining vital ecosystem services, is widely acknowledged and explicitly reflected in the UN Sustainable Development Goal (SDG) 14 and Aichi Target 11, under the CBD Strategic Plan for Biodiversity 2011-2020.[245], [246]

The 30% figure is supported by a review published in 2016 which looked at effective coverage targets for ocean protection.[247] The review looked at the findings from 144 studies, examining what proportion of the ocean should be protected to achieve various objectives. This included protecting biodiversity, ensuring that populations in different parts of a species' range can move from one MPA to another, avoiding the collapse of fisheries or specific species populations, maximising fisheries value or yield, and minimising trade-offs among stakeholders with, at times, competing interests. What the researchers' analysis found was that there is a remarkable convergence arising from the different studies, suggesting that protecting 30–40% of an ocean area is necessary to achieve many of these individual management objectives. More than half of the 144 studies concluded that at least 30% of the area under consideration had to be set aside to achieve the stated objective. Only a tiny fraction found that 10% (the existing global target) was sufficient.

Consequently, scientists from across the world are calling for full protection of at least 30% of the ocean by 2030, a call endorsed by a resolution of the IUCN's World Conservation Congress in 2016.[248] Furthermore, in September 2019 the UK announced the formation of a new alliance supporting the 30x30 initiative, pushing for at least 30% of the global ocean to be protected in MPAs by 2030. Countries supporting the UK in this initiative are Belize, Costa Rica, Finland, Gabon, Kenya, Seychelles, Vanuatu, Portugal, Palau, and Belgium.[249]

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The 'Half-Earth' proposal

The esteemed biologist Edward O. Wilson has recommended that 50% of the world should be dedicated to nature if humanity wants to save our imperilled planet.[250] In his book, Wilson describes ecological theory to note that as nature reserves are reduced in area, the diversity within them declines to a mathematically predictable degree such that, by protecting half of the world, more than 80% of species populations would become stabilised, thereby saving full representation of the world's ecosystems. In this vein, Wilson also argues that the enormity of threats to global biodiversity cannot be addressed in a piecemeal way, a view also expressed in the First Global Integrated Marine Assessment, and demands a bold solution on a commensurate scale.[251] Overall, Wilson's 'Half-Earth' proposal provides an inspirational goal for humanity which, if implemented, Wilson believes would help put fears and anxieties to rest.[252]

The need to massively scale-up protection efforts is gaining ever greater support. The team behind the Global Deal for Nature—a roadmap for simultaneously averting a sixth mass extinction and reducing climate change—have charted a course for immediate protection of at least 30% of the Earth's surface to put the brakes on biodiversity loss. They then added a further 20% 'comprising of ecosystems that can suck disproportionately large amounts of carbon out of the atmosphere'.[253]

Large-scale protected areas

Small, individual ocean sanctuaries may deliver multiple benefits and can, by establishing networks of them in coastal zones, protect local populations, ensuring that communities reliant on the ocean are able to maintain their livelihoods. However, the establishment of large-scale MPAs (LSMPAs) is crucial if we are to address the depth, breadth and cumulative impacts of multiple threats to the marine environment.[254] In the high seas, large protected areas must match the scale of large ecosystems. For example, a strong case has been presented for a large sanctuary in the Sargasso Sea, where the 'floating golden forest' of Sargassum weed provides food, shelter and a nursery for important species, many of which are endangered. It also plays a key role in the global ocean sequestration of carbon.[255,256] Wide-ranging and highly migratory species, including whales, turtles, seabirds, sharks and tuna, are also most feasibly protected with larger ocean sanctuaries.[257] LSMPAs reflect and can protect large proportions of these species' ranges and provide protected corridors that connect different habitats in a way smaller areas cannot.[258] LSMPAs mitigate threats over larger areas, maintain pristine areas and may capture shifts associated with SST and other environmental changes. Given the uncertainty of climate change impacts, increasing human activity in international waters and the cumulative impacts of all these different stressors, LSMPAs, by protecting ecologically functional swathes of ocean, act as an insurance policy for the future.[259]

Five key factors influencing ocean sanctuary outcomes

The level of protection and size are two key factors that are vitally important in determining the conservation outcomes of an MPA. However, they are not the only important features. A study of 87 MPAs worldwide found that conservation success, as indicated by fish biomass, improves exponentially when an MPA had five key characteristics. While those with four were more successful than those with fewer, they were not as successful as those with all five.[260] The key characteristics in question are:

- **No fishing is allowed**
- **Rules are enforced**
- **The MPA is more than 10 years old**
- **The MPA is larger than 100 km^2 (i.e. relatively large)**
- **The MPA is isolated from fished areas by habitat boundaries, such as deep water or sand**

Red gorgonian corals in a Marine Protected Area in Sardinia
© Egidio Trainito / Greenpeace

Whale shark in Cenderawasih Bay, Indonesia
© Paul Hilton / Greenpeace

30X30: A BLUEPRINT FOR OCEAN PROTECTION

In April 2019, Greenpeace published *30x30: A Blueprint for Ocean Protection*.[261] The report, intended to inform the ongoing negotiations for a Global Ocean Treaty, included a suggested approach for designing a network of sanctuaries in international waters. It used a 'poster child' example of a network that would give 30% coverage for each of 458 conservation features, (species, habitats or proxies thereof such as sea surface temperature and other environmental conditions), representing the full spectrum of marine life. The chosen design was one of many possible solutions derived by scientists from a systematic conservation planning exercise using the computer software programme Marxan.

The world is changing faster and in more ways than in all of human history. Entire ecosystems are restructuring and unforeseen outcomes are highly probable. For this reason, designing sanctuary networks around present conditions risks future failure. These designs must provide their protective function no matter what the future holds. In the face of uncertain future conditions, investors build portfolios to spread risks. Sanctuary networks must do the same.

Greenpeace's network design deals with environmental change and uncertainty in three ways:

1. **By portfolio building (i.e. representing a range of habitats, places and conditions across the world's oceans) as a bet hedging/risk reduction approach.**

2. **Through large coverage which promotes connectivity, stepping stones, corridors for travel and refuges of last resort.**

3. **With the novel use of historical sea surface temperature data.**

In this new approach to climate change resilience, two kinds of areas were identified for extra protection. Firstly, places with relatively high natural temperature variability, which represent ecosystems that may be inherently resilient to future change because species are adapted to fluctuating conditions and secondly, places with low variability, where change may be slower and ecosystems have more time to adapt. Collectively, these network design principles increase the chances of species and ecosystems surviving and adapting to global change.

Greenpeace's analyses show that it is possible to use the increasingly sophisticated and spatially well-resolved data available to design an ecologically representative, planet-wide network of high seas protected areas that will increase the resilience of ocean ecosystems in the face of uncertainty. Systematic conservation planning offers a key tool to inform planning decisions in a cost-effective, transparent and defensible way. Essentially, building insurance through protecting a diverse portfolio of natural systems is vital not only for the ecosystem functions protected systems offer, but also for the services that humans derive from protected areas.

> "Greenpeace's analyses show that it is possible to use the increasingly sophisticated and spatially well-resolved data available to design an ecologically representative, planet-wide network of high seas protected areas."

Smart design can reduce costs

Taking costs into consideration is an important aspect of systematic conservation planning. When developing examples of network designs for the high seas for Greenpeace, Professor Callum Roberts and his team included fishing as a cost that needed to be minimised.[262] To reduce possible negative socio-economic impacts, publicly available data on trawl, purse-seine and longline fishing from globalfishingwatch.org was incorporated into Marxan. The resulting network designs only displaced ~ 22% or 32% of existing fishing effort for 30% and 50% coverage scenarios respectively, demonstrating that networks representative of biodiversity can be built with limited economic impact. Many of the costs of establishment will in any case be offset by gains from protection, such as the rebuilding of fish stocks and improved ecosystem health.

Achieving the level of ocean protection that is needed to protect marine life, build resilience and protect the sequestration and storage of ocean carbon is going to require significant financing. Governments, the private sector and multilateral banks all have a key role to play in catalysing this transition to sustainable, nature-based marine and coastal infrastructure. It is essential that the voices of those most affected by global climate change, such as vulnerable coastal communities, are involved in developing solutions that will safeguard their futures.

> "It is essential that the voices of those most affected by global climate change, such as vulnerable coastal communities, are involved in developing solutions that will safeguard their futures."

A house floating near the New Jersey shore in the aftermath of Hurricane Sandy
© Tim Aubry / Greenpeace

Coastal erosion in Puglia, Italy
© Giuseppe Lanotte / Greenpeace

Heads of state from more than 190 nations attend the opening day of the United Nations Climate Change Conference (COP 21) in Paris, 2015

© Christophe Calais / Signatures / Greenpeace

OCEANS AND CLIMATE IN POLITICS

United Nations Framework Convention on Climate Change (UNFCCC)

In May 1992, with the adoption of the United Nations Framework Convention on Climate Change (UNFCCC), the world's governments took their first major step towards cooperating to tackle the growing threat of climate change at a global level. The UNFCCC sets out the basic legal framework and principles for international climate change cooperation, with the objective of stabilising 'greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.'[263] The convention, which entered into force on 21 March 1994, has 197 parties. It notes the role of the ocean as a carbon sink but does not include a specific stream of work on the ocean.

Paris Agreement

A significant step forward was made at the 2015 UN Climate Change Conference (COP 21) convened in Paris, France, which culminated in the adoption of the Paris Agreement on 12th December 2015.[264] It has now been ratified by 185 of the 197 Parties to the convention.[265] The agreement centres on a goal to limit global average temperature increase to well below 2°C above pre-industrial levels, whilst pursuing efforts to limit it to 1.5°C. It also aims to increase parties' ability to adapt to the adverse impacts of climate change and make financial flows consistent with a pathway towards low greenhouse gas emissions and climate resilient development.[266]

Under the Paris Agreement, at five-year intervals each party shall communicate successively more ambitious NDCs. By 2020, parties whose NDCs contain a time frame up to 2025 are requested to communicate a new NDC. Parties with an NDC time frame up to 2030 are requested to communicate or update these contributions. An important feature of the Paris Agreement includes a process known as the global stocktake, to review collective progress on mitigation, adaptation and means of implementation. Beginning in 2023, parties will convene this process at five-year intervals. In Paris, parties also agreed on the need to mobilise stronger and more ambitious climate action by all parties. Current NDCs fall far short of what is required in order to limit warming to 1.5°C and many countries, including the majority of the G20, are not on track to meet their current targets.[267]

Because the Ocean Initiative

In the years since the ratification of the UNFCCC, there has been a growing understanding of the role of the ocean with respect to climate change and, consequently, a growing call from scientists, civil society and some governments to include a dedicated workstream on the ocean-climate nexus within the UNFCCC. Just prior to the Paris COP in November 2015, the Because the Ocean Initiative was launched. 23 countries signed the first Because the Ocean Declaration, which supported a then just proposed Special Report on the Ocean by the IPCC. It also backed the convening of a high-level UN ocean conference in support of the implementation of SDG 14, which focuses on the ocean, and promoted an ocean action plan within the UN Framework Convention on Climate Change.[268] A year later at COP 22 in Marrakech, Morocco, a further 10 countries had joined the original 23 to sign a second declaration which underlines the importance of further scientific knowledge to better understand:

1. The biological interactions of marine biodiversity and ecosystems with greenhouse gas emissions and the climate system, particularly with respect to mitigation opportunities.

2. The socio-economic and environmental implications of climate change impacts on the ocean, with a view toward adaptation action. Specifically, the second declaration encourages 'UNFCCC Parties to consider submitting Nationally Determined Contributions that promote, as appropriate, ambitious climate action in order to minimize the adverse effects of climate change in the ocean and to contribute to its protection and conservation.'

The Because the Ocean Initiative continues to be developed through a series of international workshops and, as of July 2019, is supported by 39 signatories: Aruba, Australia, Belgium, Canada, Chile, Colombia, Costa Rica, Dominican Republic, Fiji, Finland, France, Guatemala, Guinea Bissau, Haiti, Honduras, Indonesia, Italy, Jordan, Kiribati, Luxembourg, Madagascar, Marshall Islands, Malta, Mexico, Monaco, Morocco, The Netherlands, New Zealand, Norway, Palau, Peru, Romania, Senegal, Seychelles, Singapore, Spain, Sweden, Uruguay, UK. The 'red threads' that run through this work are that ocean action is critical for climate action, ocean-related mitigation and adaptation measures can help countries increase their climate ambition and it is necessary to strengthen the science-policy relationship for better informed decision-making for ocean action.

The Ocean Pathway

The Ocean Pathway is another political process that was successfully launched in COP 23 in Bonn, Germany. It is a two-track strategy for 2020 supporting the goals of the Paris Agreement that includes:

1. Increasing the role of the ocean considerations in the UNFCCC process.
2. Significantly increasing action in priority areas impacting or impacted by ocean and climate change.[269]

This initiative, co-chaired by the Fiji Minister of Economy and Minister Responsible for Climate Change, Hon. Aiyaz Sayed Khaiyum, and Deputy Prime Minister of Sweden, Hon. Isabella Lövin, focuses especially on countries on the frontline of both ocean change and climate change.

Special Report on the Ocean and the Cryosphere in a Changing Ocean (SROCCC)

The growing call for the IPCC to prepare a report on climate change and the ocean was heeded with the decision to prepare a Special Report on the Ocean and Cryosphere in a Changing Climate (SROCCC) made by the IPCC Panel at its 43rd meeting held in April 2016 in Nairobi. The report, published in September 2019, assesses the latest scientific literature addressing climate change, the ocean and the cryosphere. Its purpose is to add to our knowledge on a range of topics, from water supplies for people living in high-mountain areas to the risks of sea level rise for coastal communities, as well as the broader climate-related changes that will directly or indirectly impact all people on Earth.[270] The report details the pervasive ocean and cryosphere changes already taking place. It shows how, if these impacts are allowed to continue, various unabated tipping points will be reached, bringing with them huge costs.[271] Just in monetary terms, declines in ocean health and services are projected to cost the global economy $428 billion per year by 2050 and $1.979 trillion per year by 2100. The impacts of extensive changes to marine biodiversity and ecosystem services for people will be immense, driving changes in agriculture, tourism and other key sectors involving millions of people. The report underscores the ecological imperative of greenhouse gas emission reduction in line with 1.5°C, but also reveals the benefits of ambitious and effective adaptation for sustainable development. The stark nature of the escalating costs and risks of delayed action mean that choices made now are critical for the future of our ocean and cryosphere.

> "Declines in ocean health and services are projected to cost the global economy $428 billion per year by 2050 and $1.979 trillion per year by 2100."

As outlined in the introduction, the interlinkages between ocean, climate and sustainable development are finally being discussed within the policy arena and there is a growing realisation of the need for integrated action within the key political processes. For example, this momentum is reflected in the 2019 Our Ocean programme concept which states that, 'Our future depends on clean and healthy oceans, where protection and sustainable use go hand in hand. The oceans have a crucial role to play if we are to achieve the UN SDGs but are under threat from the effects of climate change, pollution, loss of biodiversity and unsustainable use. Safeguarding the oceans for future generations is a shared responsibility and a matter of global urgency.'[272]

In January 2018 a new global partnership, the Friends of Ocean Action, was launched at the World Economic Forum Annual Meeting in Davos by Isabella Lövin and Peter Thomson, UN Special Envoy for the Ocean.[273] The Friends of Ocean Action is a multi-stakeholder partnership comprised of influential leaders from science, technology, business and non-governmental groups, with the purpose of scaling up and accelerating global action to deliver the UN SDG 14 (to conserve and sustainably use the oceans, seas and marine resources). The cross-sectoral make-up of the group shows that the close relationship between clean and healthy oceans, economic growth and development are now well understood and that action to protect the ocean is being seen as both a necessity and an opportunity.

Upcoming opportunities

Despite the rhetoric, it is clear that not enough progress is being made, nor are the issues of climate change and ocean protection being dealt with at the urgency and scale required. It is therefore crucial that Governments work at a national, regional and international scale to raise ambition and turn words into action, in particular with regards to the creation of a network of ocean sanctuaries. The bringing together of the ocean and climate agendas will be vital to the success of a variety of political processes including the UNFCCC COP 25 in December 2019 through elevated climate action as a response to the IPCC SROCC. Climate change also provides a key motivation for progress at the ongoing UN Global Treaty negotiations where civil society, scientists and an increasing number of governments are calling for an ambitious treaty that could establish and manage fully protected areas in international waters.

> "It is vital that in 2020 every opportunity for ambitious international action on ocean protection and climate change is seized."

Looking further ahead, there are opportunities at the UN SDG 14 Ocean Conference in June 2020 and the CBD COP in October 2020, where post-Aichi protection targets will be on the agenda as well as consideration of a target of 30% ocean protection by 2030. Finally, it is clear that nature-based climate solutions will feature on the UNFCCC COP 26 programme in November 2020. Each of these opportunities for ambitious international action on ocean protection and climate change must be seized to reverse the trend of weaker, voluntary measures adopted by a coalition of the willing such as some of those initiatives outlined above.

An octopus crawling across a seagrass bed at night
© Roger Grace / Greenpeace

A Weddell seal and gentoo penguin on Greenwich Island, Antarctica

© Paul Hilton / Greenpeace

TIME FOR ACTION

> "Never before have we had such awareness of what we are doing to the planet. Never before have we had such power to do something about it."
>
> —David Attenborough

In this report, we have set out how important the ocean and ocean ecosystems are for carbon cycling, sequestration and storage. We have explored how the oceans contribute to the regulation of the Earth's climate, how they are currently under assault from a range of threats associated with the rapid increase of human-induced emissions of CO_2, and how other destructive and extractive human activities, such as deep sea mining and overfishing, compound these threats. The ways in which climate change and these threats interact is unpredictable and worrying. Major disruption of ocean ecosystems is already occurring with knock-on consequences for the ecosystem services they provide. The need for urgent action could not be more stark.

The science is crystal clear: climate-related risks for natural and human systems are lower for global warming of 1.5°C than at 2°C. These risks will be shaped by a multitude of factors, including the magnitude and rate of warming, geographic location, levels of development and vulnerability, and the choices and implementation of adaptation and mitigation options.[274] For example, the probability of a sea-ice-free Arctic summer increases tenfold, from once a century at 1.5°C warming to once a decade at 2°C. 2°C virtually wipes out coral reefs, compared to a 70-90% decline at 1.5°C.[275]

Taking in the magnitude and pace of the climate emergency, it is therefore incumbent on the Parties to the Paris Agreement to both ramp up ambition and take drastic action to slash emissions. Current pledges won't limit climate change to 2°C, let alone 1.5°C. Countries must commit, as soon as possible and no later than 2020, to strengthening national climate plans and associated NDCs in line with the 1.5°C limit. It is also vital that finance and support for poor and vulnerable countries is both scaled-up and assured.

However, a fundamental shortcoming of the Paris Agreement is that it does not safeguard the diversity of life on Earth. Many scientists and others believe that unless there is concerted action to save the Earth's biodiversity, conducted together with the efforts to slash emissions, the ambitions of the Paris Agreement will not be met, not least because protecting and restoring natural ecosystems, including those in the marine realm, are essential for sequestering and storing carbon.

Beginning with the UNFCCC COP 25 in December 2019 and running up until the CBD meeting in October 2020, the next year sees a series of global political meetings that collectively constitute a unique window of opportunity for the world's governments. They must take the necessary steps to integrate the various political processes, harness synergies and make decisions that will bring about transformative changes. These changes must address climate breakdown, biodiversity loss and ocean protection at a global scale and make significant progress towards achieving a number of the agreed SDGs. Increasingly, 2020 is being seen as a once in a generation opportunity that we cannot squander or, as David Attenborough said at the end of his Blue Planet 2 series, 'Never before have we had such awareness of what we are doing to the planet. Never before have we had such power to do something about it.'

A failure to act immediately will not only have dire repercussions for marine life, but for each and every one of us.

Greenpeace demands that the world's governments act individually, cooperatively and across multiple climate and oceans fora to mitigate the worst impacts of increasing anthropogenic CO_2 emissions and build ocean resilience.

Here are five essential steps to achieve this:

1. Raise ambition and take action to phase-out fossil fuel emissions.

Countries must commit, as soon as possible and no later than 2020, to strengthening national climate plans and associated NDCs in line with the 1.5°C limit.

2. States must agree a strong UN Global Ocean Treaty by 2020.

The treaty must enable the establishment, effective management and enforcement of a global network of fully protected areas in areas beyond national jurisdiction and ensure that proper environmental impact assessments are carried out. The treaty must also be supported by a global decision-making body in the form of a Conference of Parties, through which states would act collectively to establish ocean sanctuaries and agree necessary conservation measures. This must be supported by an independent scientific committee and adequate financing.

3. The CBD must agree a '30x30' target.

At CBD COP15 in China, states will negotiate new protection targets for the next decade. The target for marine biodiversity should be to protect at least 30% of the ocean through the implementation of ocean sanctuaries, with the remaining 70% of the ocean sustainably managed.

4. States must establish networks of strongly protected areas within their national waters.

National networks of ocean sanctuaries must be established and these should cover at least 30% of national waters by 2030. Priority should be given to preserving coastal blue carbon habitats. To ensure the effectiveness of these national networks, they must be established in consultation with stakeholders and especially the Indigenous and coastal communities that depend on the ocean for their livelihoods. Establishing national networks will not be sufficient to protect the marine environment alone and activities, including fishing outside the protected area network, must be managed sustainably.

5. States must agree to ban deep sea mining—at a time when the ocean is facing more threats than ever before.

There is no evidence to suggest that deep sea mining can be managed in a way that ensures the effective protection of the marine environment and prevents loss of biodiversity.[276]

Conclusion

Burning fossil fuels and other human activities like fishing, mining and polluting the ocean have caused a swift and alarming decline of wildlife and the degradation of ocean habitats. Not only are these pressures detrimental to the wellbeing of ocean life, they compromise the ability of ocean ecosystems to deliver key functions that sustain us all, and keep the planet healthy, a problem that will be further exacerbated by global climate change. To avert looming ecological tipping points, we must implement effective protection at a commensurate scale and with absolute urgency.

Beluga whales feeding at the ice edge in the Arctic
© Christian Åslund / Greenpeace

Sunrise over a reef in Komodo National Park, Indonesia
© Paul Hilton / Greenpeace

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30X30

IN HOT WATER: THE CLIMATE CRISIS AND THE URGENT NEED FOR OCEAN PROTECTION

Burning fossil fuels and other human activities like fishing, mining and ocean pollution have caused a swift and alarming decline of wildlife and the degradation of ocean habitats.

Not only are these pressures detrimental to the wellbeing of ocean life, they compromise the ability of ocean ecosystems to deliver key functions that sustain us all and keep the planet healthy—a problem that will be further exacerbated by global climate change.

To avert looming ecological tipping points, we must implement effective protection at a commensurate scale and with absolute urgency.

This report explores the multitude of threats facing our oceans and what needs to be done to mitigate the worse impacts of climate change.

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'Cleaner' fish hitch a ride with a turtle in Elphinstone Reef, Egypt
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