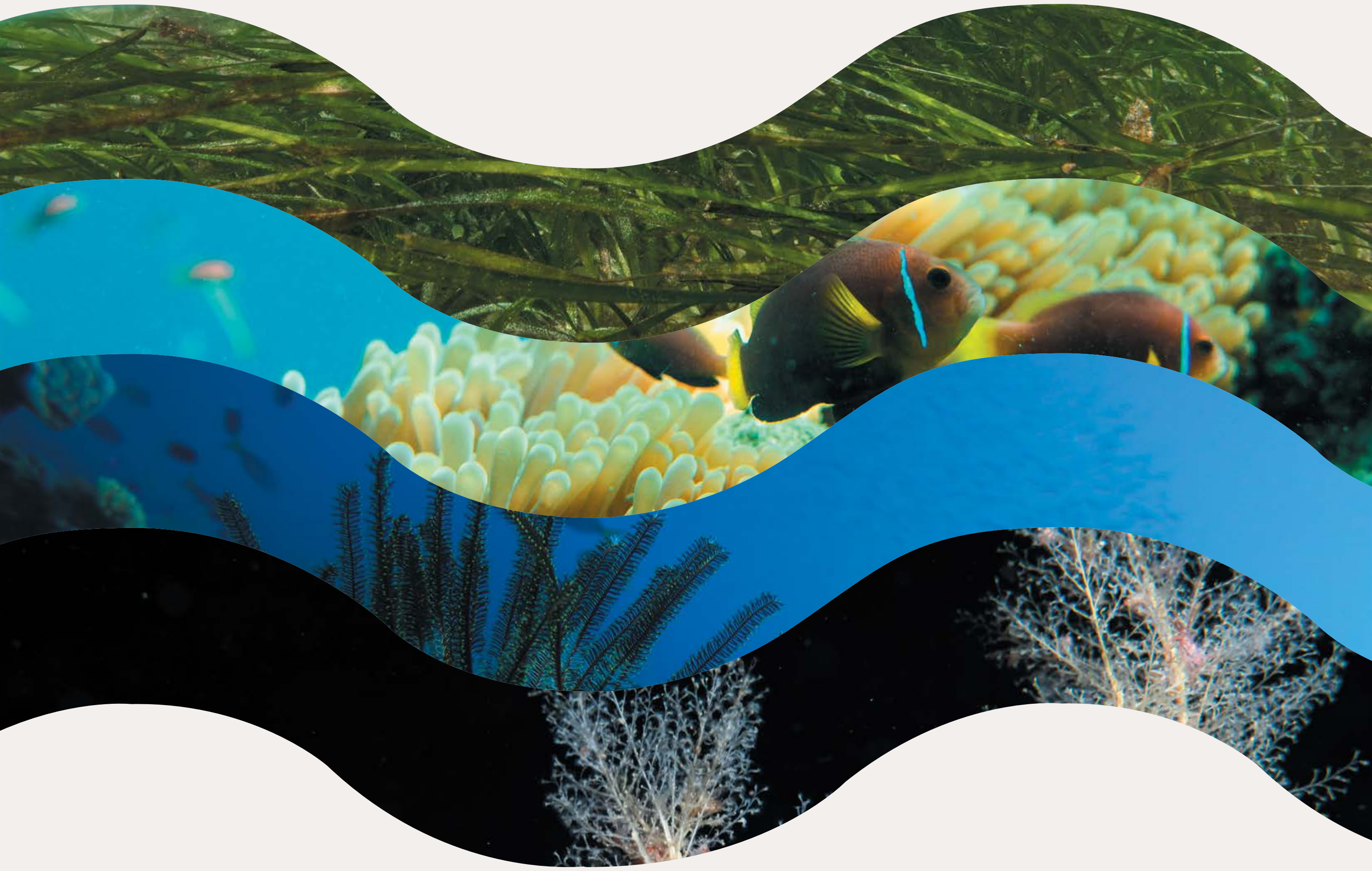
WHAT OCEAN FOR TOMORROW?
MARINE ECOSYSTEMS IN A CHANGING CLIMATE

Insights from the IPCC's Sixth Assessment Report



OCEAN & CLIMATE PLATFORM

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About the Ocean & Climate Platform

OCEAN & CLIMATE PLATFORM

The Ocean & Climate Platform (OCP) aims to promote a constructive dialogue among the scientific community, civil society and policy-makers. Bringing together more than 100 organisations across the world - including research institutes, NGOs, foundations, scientific mediation organisations, private sector entities, local authorities - the OCP draws on scientific knowledge and promotes ocean-based solutions to preserve the ocean, its biodiversity and the climate. Leading organisation of the ocean-climate community, the OCP has become an observer organisation to the United Nations Conventions on Climate Change (UNFCCC) and Biodiversity (CBD) and contributes to the French governmental review of the IPCC reports. In this respect, the activities of the OCP aims to contribute to the United Nations Decade of Ocean Science for Sustainable Development (2021-2030).

Sharing knowledge on the ocean based on the IPCC reports

Since 2018, the OCP mobilises its scientific and science mediation networks to participate in the French governmental review of the ocean-related chapters of the IPCC reports. The Platform has contributed to the review of the Special Report on Global Warming of 1.5°C (2018), the Special Report on the Ocean and Cryosphere in a Changing Climate (2019) as well as the Sixth Assessment Report (2021-2023). Promoting and enhancing knowledge appropriation on ocean-climate-biodiversity interactions, the OCP convenes a community of science mediation experts to produce accessible contents intended for decision-makers and the general public. In 2019, the Platform published "Ocean & Climate Change: New Challenges", based on the Special Report on the Ocean and Cryosphere. In 2023, the OCP is pursuing this work with the release of "What ocean for tomorrow? Marine ecosystems in a changing climate, Insights from the IPCC's Sixth Assessment Report". Drawing from the IPCC Sixth Assessment Report, this new publication provides a synthesis on current knowledge about the linkages between marine ecosystems, climate change and sustainable development.

H.S.H. PRINCE ALBERT II OF MONACO

Monaco, February 2023

In 2022, the IPCC published its sixth assessment report (AR6), which drew attention to accelerating climate change. Its conclusions are extremely clear: without an immediate and urgent scale-up of climate action, we will head towards a median global warming of 3.2°C by the end of the century, instead of the 1.5°C stated in the Paris Agreement.

As pointed out by the IPCC report, the impacts of climate change on the ocean are already visible and will become exacerbated as greenhouse gas emissions and anthropogenic pressures increase. The ocean - a key component of the climate system and representing the largest living environment on our planet - is deteriorating, thereby threatening marine biodiversity and beyond that, our human society. However, the ocean is still a source of hope, capable of responding to the climate and biodiversity crises. Since the inclusion of the ocean in the Preamble to the Paris Agreement at COP 21, significant progress has been made for the Ocean and 2022 marked this positive development.

From the One Ocean Summit in Brest to COP 15 on biodiversity in Montreal, not to mention the United Nations Conference on the ocean in Lisbon, the international community has firmly placed ocean-climatebiodiversity issues amongst its concerns and has brought to the fore several ocean-based solutions to address climate change and loss of biodiversity.

Providing a summary of knowledge on past, present and future climates, the IPCC report also highlighted a number of sustainable courses of action. In this respect, marine ecosystems, critical elements for the overall balance of our planet, are key aspects of the response, both for mitigation and adaptation.

The publication produced by the Ocean & Climate Platform (OCP) of which several organisations in the Principality of Monaco are members, including the Monaco Scientific Centre, the Oceanographic institute - Albert 1, Prince of Monaco Foundation, the Monegasque Association on Ocean Acidification (OACIS) and my Foundation, will help us to gain a better understanding of these issues.

This publication is primarily targeted at decision-makers, coastal and blue economy stakeholders, but also anyone who would like to learn more about and take action for the climate, ocean and biodiversity.

I hope it will offer everyone the opportunity to become more aware of the challenges faced by our world, and to capitalise further on science to lead us towards a more sustainable world.

H.E. RAZAN AL MUBARAK,
UN CLIMATE CHANGE HIGH-LEVEL CHAMPION FOR COP28

Oceans are at the crossroads of all major challenges facing humanity today, with climate change, biodiversity loss, pollution, and anthropogenic pressure threatening their health. Our well-being and that of future generations - our cultures, identities, the food we eat and the air we breathe - are deeply intertwined with the ocean. It is urgent that we address these global threats to preserve marine life and restore the fundamental, yet fragile connection between humans and nature.

We must remain hopeful: the ocean and its ecosystems are one of our greatest allies against these crises. If given the chance, the marine and coastal ecosystems that are home to an astounding diversity of species can bounce back. We must recognise their irreplaceable value. The natural carbon-storage capacity of these ecosystems makes them immensely powerful in mitigating climate change. Considering that by 2050, close to a billion people could be living in coastal zones less than ten meters above sea level, the ability of marine ecosystems to act as buffers against sea level rise and extreme events is one our greatest chances to adapt. Safeguarding the health of marine and coastal ecosystems can help us not only survive the impacts of climate change, but also thrive in spite of them.

It is our responsibility to put oceans on a path to recovery. I am delighted to see marine Nature-based Solutions acknowledged by the scientific community as critical levers to deliver on our goals to limit climate change and halt biodiversity loss, while providing cascading benefits for coastal communities. Nonetheless, these solutions will not be sufficient if not met with ambitious and bold climate policies, guided by scientific work such as the IPCC's Sixth Assessment Report.

With the synthesis "What Ocean for Tomorrow? Marine ecosystems in a changing climate, Insights from the IPCC's Sixth Assessment Report", the Ocean & Climate Platform pursues its long-standing mission to promote the accessibility and appropriation of knowledge to lead action. This synthesis is a critical publication for policymakers, negotiators, non-state actors and all those who care for the ocean to understand the urgency we face and take informed decisions towards a resilient future.

Achieving our goals will require strong mobilisation from all actors across sectors. Guided by the principle of inclusivity, I will utilize my platform as UN Climate Change High-Level Champion for COP28 to work hand in hand with civil society and Parties to put nature at the heart of the narrative and keep the target of +1.5°C within reach.

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Introduction

The ocean and its ***ecosystems*** are essential to sustain life on Earth and meet human needs. Covering over two thirds of the planet's surface, the ocean plays a crucial role in the climate system by regulating heat transfers, water and carbon cycles, among others. Since the beginning of the Industrial Revolution the ocean has absorbed close to a third of all ***greenhouse gases*** emissions and 90% of the heat produced by human activities.

The ocean is a reservoir of biodiversity and the world's largest habitable zone by volume. It is home to a wide variety of ecosystems which include coral reefs, mangroves, ***salt marshes***, as well as kelp forests and seagrass meadows. These environments play an essential role in maintaining species diversity. They have a cultural value for many communities and provide food, minerals, energy and jobs for human populations.

Climate change is exposing marine ecosystems to conditions that have not been experienced for millennia. Its impacts on life in the ocean are considerable and compounded by human activities such as fishing, oil exploitation, shipping and coastal development.

In consequence, marine ecosystems are becoming increasingly less capable of maintaining the essential services they provide, including in terms of climate regulation. All life, whether in the sea or on land, is greatly affected. As the impacts of climate change accelerate and intensify, the conservation of marine ecosystems becomes even more critical. To ensure the proper understanding of these phenomena by the greatest number of people, and to improve the inclusion of marine ecosystems in climate and environmental policies, the Ocean & Climate Platform and its members are publishing **"What ocean for tomorrow? Marine ecosystems in a changing climate, Insights from the IPCC's Sixth Assessment Report"**, a summary of the key issues on marine ecosystems explored in the IPCC's Sixth Assessment Report (AR6). The purpose of this publication is to provide answers to the following questions:

- **What services do marine ecosystems provide?**
- **What are the consequences of deteriorating marine ecosystems?**
- **How can the protection of marine ecosystems help us achieve a sustainable future?**

What ocean for tomorrow?

In a context of growing impacts from climate change and human activities, marine ecosystems are degrading, increasing the vulnerability of living species and human societies.

To mitigate and adapt to the impacts of climate change, it is urgent to better protect and restore marine ecosystems. Healthy marine ecosystems are essential to a sustainable world.

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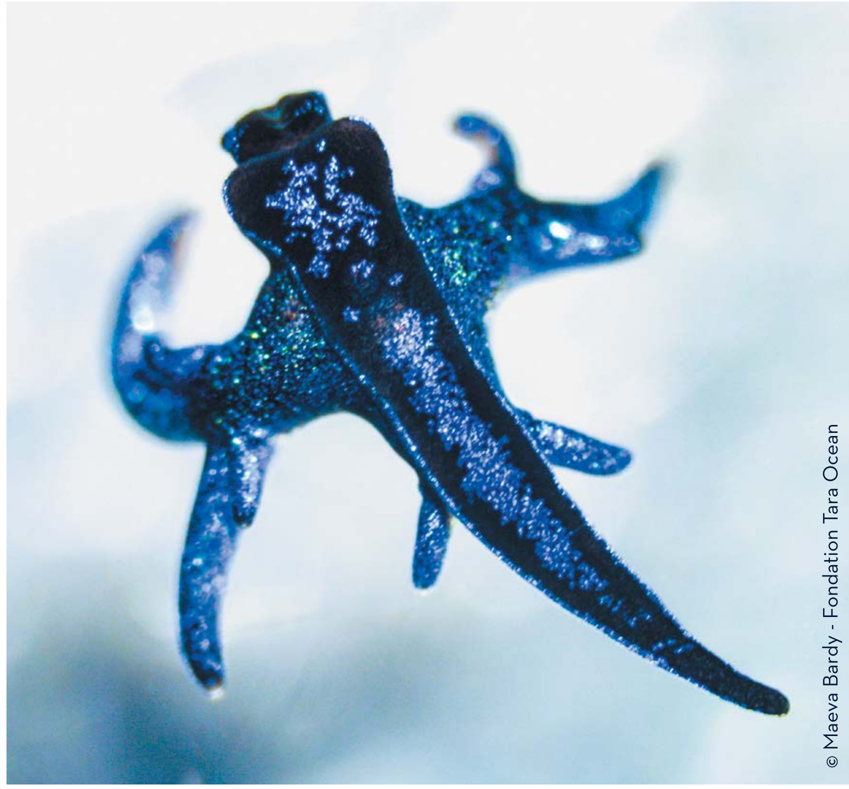
WHAT SERVICES DO MARINE ECOSYSTEMS PROVIDE?

1 MARINE ECOSYSTEMS REGULATE THE EFFECTS OF CLIMATE CHANGE

The ocean is the greatest single influence on the Earth's climate as it absorbs close to 30% of the CO_2 emissions from human activities.

- 90% of this process is physical and chemical: CO_2 from the atmosphere dissolves into the water at the surface of the sea and is then transported by marine currents into the depths.
- 10% of this process is biological through the photosynthetic activities of phytoplankton and various marine plants. In coastal areas, the so-called "***blue carbon ecosystems***", such as mangroves, seagrass meadows and salt marshes, sequester and store carbon in vast quantities. They absorb between 0.5% and 2% of our CO_2 emissions, thereby contributing to climate-change ***mitigation***.



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FOCUS

PLANKTON: ESSENTIAL TO ALL LIFE ON EARTH

Plankton consists of all the floating organisms, microscopic for the most part, living in suspension in the upper layers of the ocean. They account for more than 95% of the marine biomass and are characterised by a remarkable diversity, which includes viruses, microalgae, reproductive cells, fish larvae, micro-crustaceans, and jellyfish. There are two types of plankton. Plant plankton, also called phytoplankton, produce their own energy from sunlight through photosynthesis. Animal plankton, or zooplankton, feed on phytoplankton and other zooplankton for their energy.

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Why are phytoplankton important for the biological carbon pump?

Phytoplankton are a key component of the biological carbon pump. They capture atmospheric CO_2 in the surface layer of the ocean through photosynthesis to produce organic matter; a process known as ***primary production***. The part of this organic matter which is not eaten by zooplankton or bigger organisms, sinks from the surface as tiny particles and accumulates at the bottom of the ocean. After millions of years, and in the right conditions, this carbon-rich matter turns into oil or gas in the deepest parts of the ocean.

How does climate change affect plankton?

Plankton populations are affected by climate change in various ways:

- → Rising temperatures are driving the ***stratification*** of the upper layers of the ocean. This modifies the quantity of plankton, their geographic distribution, the number and diversity of species. It also affects photosynthesis by altering the access to necessary ***nutrients***.
- → ***Acidification***, resulting from an increase of CO_2 dissolved in the ocean, also disrupts plankton. Many phytoplanktonic organisms have a shell or skeleton made of calcium carbonate which they struggle to form in more acidic waters.
- → As a result, primary production and the efficiency of the biological carbon pump are negatively impacted. All these upheavals undermine the ability of the ocean and its ecosystems to mitigate climate change.

What are the consequences for the food chain?

All marine organisms depend directly or indirectly on plankton for their food. Therefore, disruptions to planktonic communities have consequences on all food chains and threaten the existence of many species. While uncertainties remain as to the extent of the impact of climate change on plankton, projections forecast a decline in their overall biomass. All the animal biomass in the ocean will thus be affected, leading to consequences on fisheries and food security for many human populations.

Overall, healthy marine ecosystems provide many services and improve the capacity of living beings to withstand disruptions from climate change and human activities. Some ecosystems contribute in particular to preserving the quality of air, soil and water by filtering out pollutants and particles. They also regulate acidity and oxygenation, and protect coastlines.

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Mangroves are a good example. These coastal forests, which are found mostly in tropical and subtropical regions, have adapted to high levels of salinity. They can:

- *Store carbon in their vegetation and in the soil. They contain the largest quantities of carbon per hectare.*
- *Preserve water quality by trapping or eliminating waste (heavy metals, pesticides, hydrocarbons, etc.) and other pathogens found in the water.*
- *Protect coastlines by attenuating erosion and offering natural protection against flooding, wave energy, tsunamis and other extreme weather events.*
- *Ensure the food security of human populations by maintaining the living conditions of many animal and plant species.*

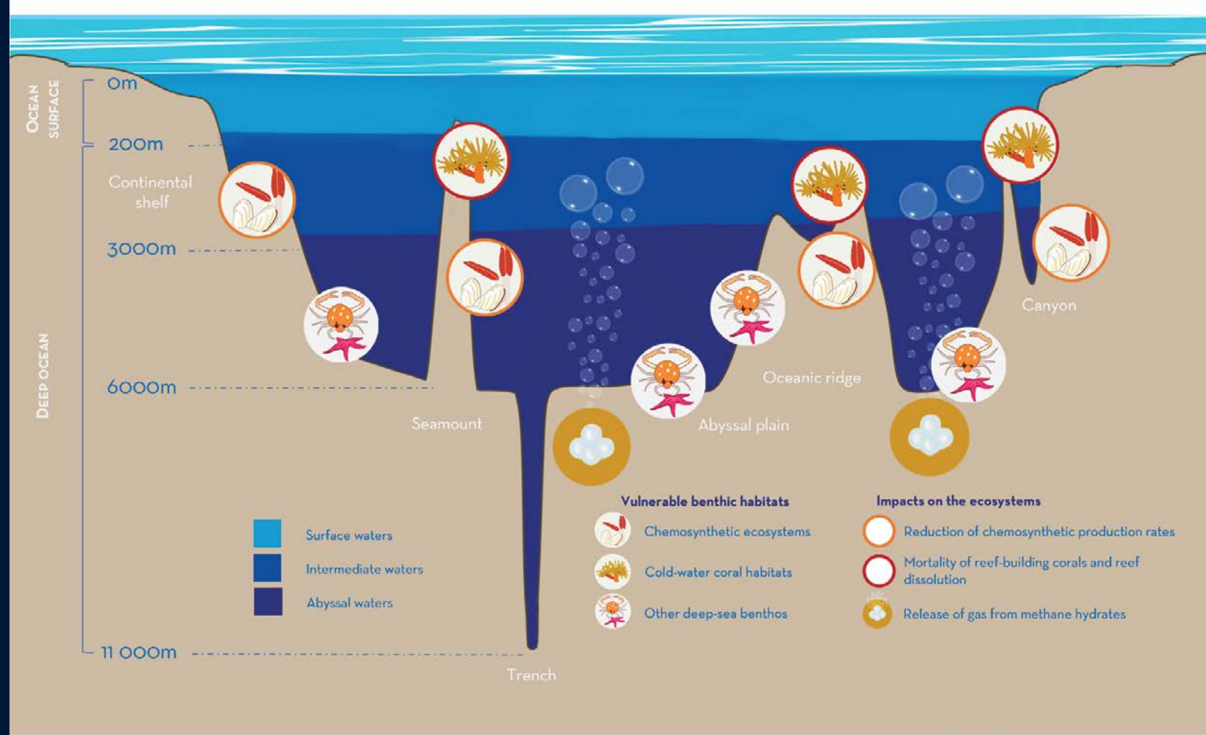
THE DEEP SEA: THE WORLD'S LARGEST RESERVOIR OF BIODIVERSITY

The deep sea starts at a depth of 200 metres. It represents over 63% of the world's surface and 95% of the ocean's volume. It is home to a highly diverse fauna and flora which develops for the most part on and around hydrothermal vents, abyssal hills and plains, and submarine canyons. Deep sea ecosystems play a crucial role in the sequestration of carbon and the cycle of other nutrients that are necessary to maintain the good health of the ocean and its biodiversity.

Our knowledge of the functioning of the deep ocean and how changes are disrupting its ecosystems is still in its infancy and incomplete. This is due to the difficulty of reaching such extreme environments, making data collection and impact assessments particularly complex.

Nevertheless, observations indicate that the deep sea and its ecosystems are not spared by climate change.

FIGURE 1: IMPACTS OF CLIMATE CHANGE ON DEEP-SEA ECOSYSTEMS



Schematic adapted from the IPCC "Schematic of the combination of climate-induced drivers in different deep-ocean ecosystems"

- Upheavals in the abyss affect the upper and surface layers of the ocean. Warming of the deep sea has direct consequences on ocean circulation, oxygen loss and the stratification of the water column.
- Such phenomena destabilise the distribution and health of species. For example, rising temperatures and changes in marine currents cause ***methane hydrates*** buried in the ocean floor, and hitherto trapped in ice, to dissolve. Their dissolution modifies ecosystems in the deeper and intermediary layers of the ocean and can, as a result, increase the concentration of greenhouse gases such as methane and CO_2 in the atmosphere.
- Deep sea corals and other habitat-forming species, such as gorgonians and sponges, are particularly sensitive to variations in temperature, oxygen and acidity. Their deterioration exacerbates the vulnerability of other species which find shelter and food in their habitats.

Other stresses linked to human activities also alter these ecosystems, such as overfishing and destructive fishing practices on the seafloor, gas and oil extraction, and even the laying of subsea cables for telecommunications. The potential exploitation of mineral resources is an additional threat heavily weighting on deep sea ecosystems. Hitherto existing in stable conditions, deep sea ecosystems are struggling to resist, adapt and regenerate in the context of rapid upheavals caused by climate change and human activities.

2 MARINE ECOSYSTEMS ARE CORNERSTONES OF OCEANIC LIFE

Ecosystems and marine biodiversity are closely intertwined. Marine biodiversity extends beyond the notion of diversity between and within species living in the ocean. It also designates the diversity of the ecosystems in which they evolve. Nearly 300,000 species have so far been identified in the ocean and undoubtedly several million more have yet to be discovered. They are all essential to the proper functioning of ecosystems, and each is dependent on the good health of the whole.

Certain marine ecosystems provide habitats and shelter for numerous species to feed, reproduce and grow. Such environments allow entire communities of living beings to develop and interact.

For example, kelp forests are crucial ecosystems which provide habitat and shelter for fish, crustaceans, invertebrates, marine mammals and others. Present on nearly 25% of the world's coasts, these ecosystems formed by macro-algae :

- *are feeding, predation, and breeding grounds;*
- *produce oxygen;*
- *store carbon; and*
- regulate water acidification.

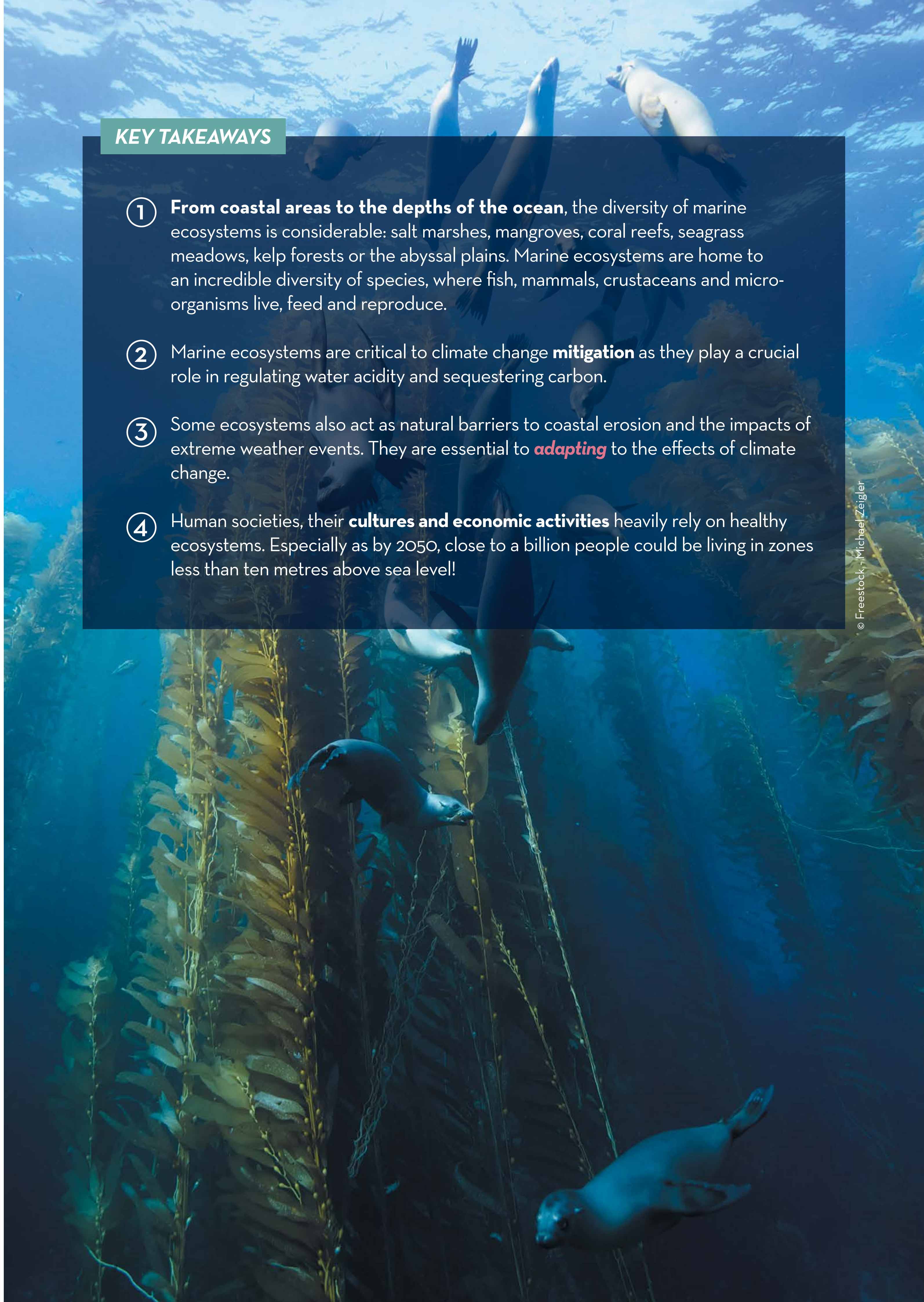
3 MARINE ECOSYSTEMS SUSTAIN HUMAN SOCIETIES

In addition to their climatic and ecological roles, marine ecosystems are particularly important to our societies. They guarantee food security. More than three billion people depend on marine resources for food, amounting to 40% of the world's population. They are closely linked to health issues as they provide biological resources which can be turned into medicine. They are also sources of energy and materials for our economies and infrastructures.

Coastal areas are home to numerous ecosystems, such as dunes, rocky coasts and wetlands, where innumerable human activities take place. They are culturally and economically rich areas which have historically attracted dense populations and continue to do so. As such, they are particularly vulnerable to sea level rise and extreme weather events. The trend is set to become more acute, as by 2050 close to a billion people are expected to be living in coastal zones that are less than ten metres above sea level.

For example, coral reefs are home to almost 30% of the world's biodiversity and are particularly important to human societies:

- *Many people depend directly on coral reefs for their sustenance;*
- *In certain regions, such as the Coral Triangle which stretches from Malaysia to Indonesia, and includes the Philippines and the Solomon Islands, coral reefs are an important source of employment for local communities (fishing, tourism, recreation, etc.);*
- *They contribute to protecting the coastline, with some coral reefs absorbing up to 97% of wave energy;*
- *They hold a special place in many cultures. For example, the Great Barrier Reef lying off the coast of Australia is one of the most spectacular maritime sites in the world. It was added to UNESCO's World Heritage list in 1981.*



KEY TAKEAWAYS

1. **From coastal areas to the depths of the ocean**, the diversity of marine ecosystems is considerable: salt marshes, mangroves, coral reefs, seagrass meadows, kelp forests or the abyssal plains. Marine ecosystems are home to an incredible diversity of species, where fish, mammals, crustaceans and micro-organisms live, feed and reproduce.
2. Marine ecosystems are critical to climate change **mitigation** as they play a crucial role in regulating water acidity and sequestering carbon.
3. Some ecosystems also act as natural barriers to coastal erosion and the impacts of extreme weather events. They are essential to ***adapting*** to the effects of climate change.
4. Human societies, their **cultures and economic activities** heavily rely on healthy ecosystems. Especially as by 2050, close to a billion people could be living in zones less than ten metres above sea level!

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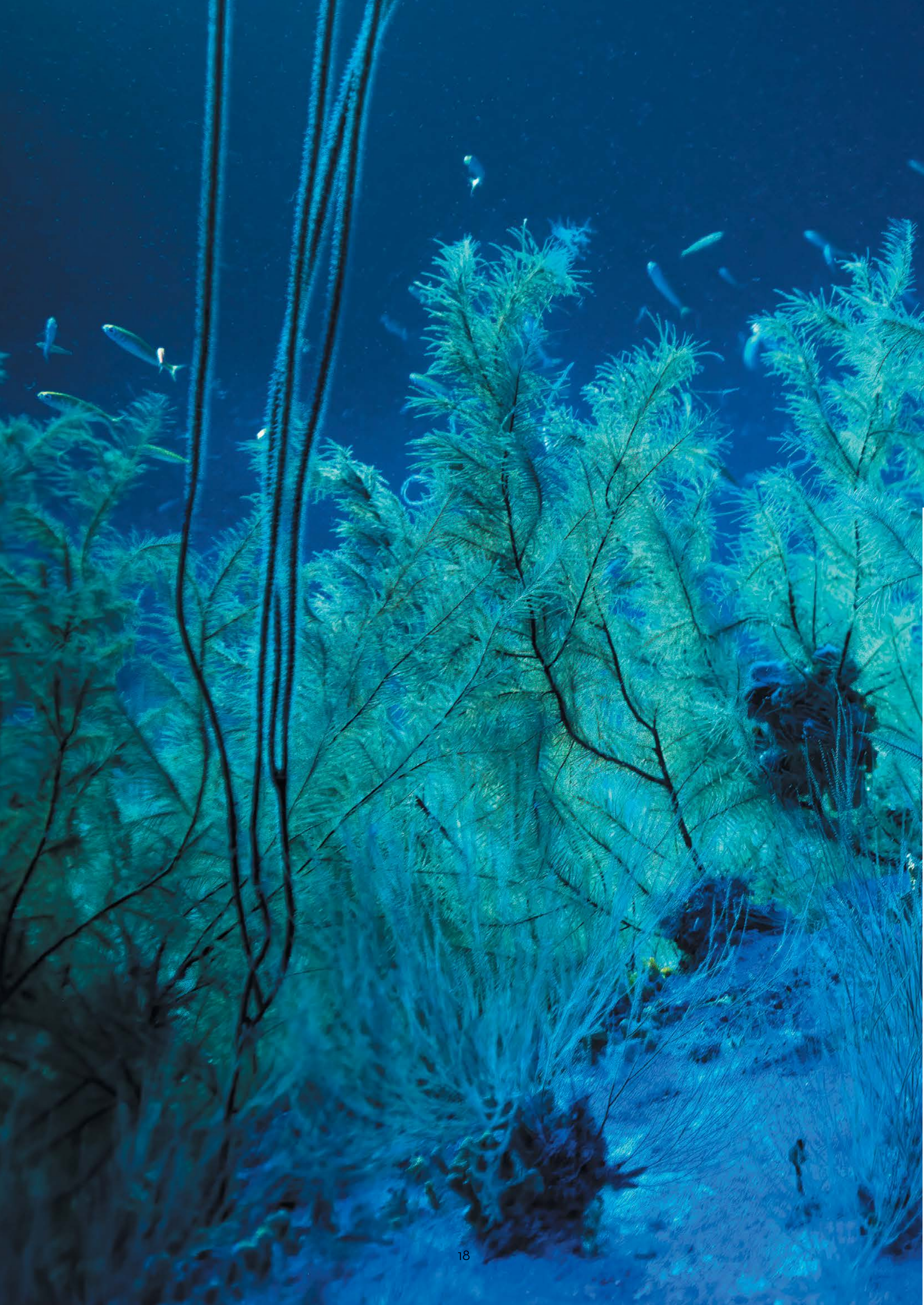

WHAT ARE THE CONSEQUENCES OF DEGRADING MARINE ECOSYSTEMS?

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1 MARINE ECOSYSTEMS ARE INCREASINGLY VULNERABLE TO CLIMATIC AND HUMAN STRESSORS

As greenhouse gases emissions increase, the atmosphere continues to warm, thereby causing major changes in the ocean:

- **Ocean warming** and more frequent and intense marine heatwaves.
- **Changes in ocean circulation,** including an increasing stratification of the upper ocean and modifications of ***upwelling systems.***
- **Sea-level rise,** partially responsible for more frequent and intense extreme weather events.
- **Chemical changes,** including acidification, changing levels of salinity, a gradual deoxygenation of water masses, an enlargement of ***dead zones***, and a reduction in nutrient production.
- **Decline of sea ice cover** in the Arctic.

These global changes are compounded by the impacts of human activities. Certain fishing techniques, pollutions, the introduction of invasive species, ***land-use change***, soil degradation and urbanisation are additional stressors threatening ecosystems. Measures to protect and manage the marine environment are currently insufficient to minimise the impacts of human activities. Only 8% of the ocean is currently under some level of protection regime.

Damaged ecosystems can, in turn, exacerbate the consequences of climate change. As underscored by the IPCC: **"when degraded or lost, coastal blue carbon ecosystems are likely to release most of their carbon back into the atmosphere."**

2 MARINE ECOSYSTEMS STRUGGLE TO ADAPT

The acclimation capacity of ecosystems to climatic and non-climatic stressors varies and depends on a number of factors:

- *The type and geographic location of habitats expose ecosystems to varying degrees of risk;*
- *The reaction of organisms depends on the intensity and duration of their exposure to climatic and human-related stresses;*
- *The reaction of organisms depends, among others, on their individual behaviours and their position in the food chain.*

FIGURE 2: EXAMPLES OF TIPPING POINTS REACHED BY KELP FOREST AND REEF ECOSYSTEMS

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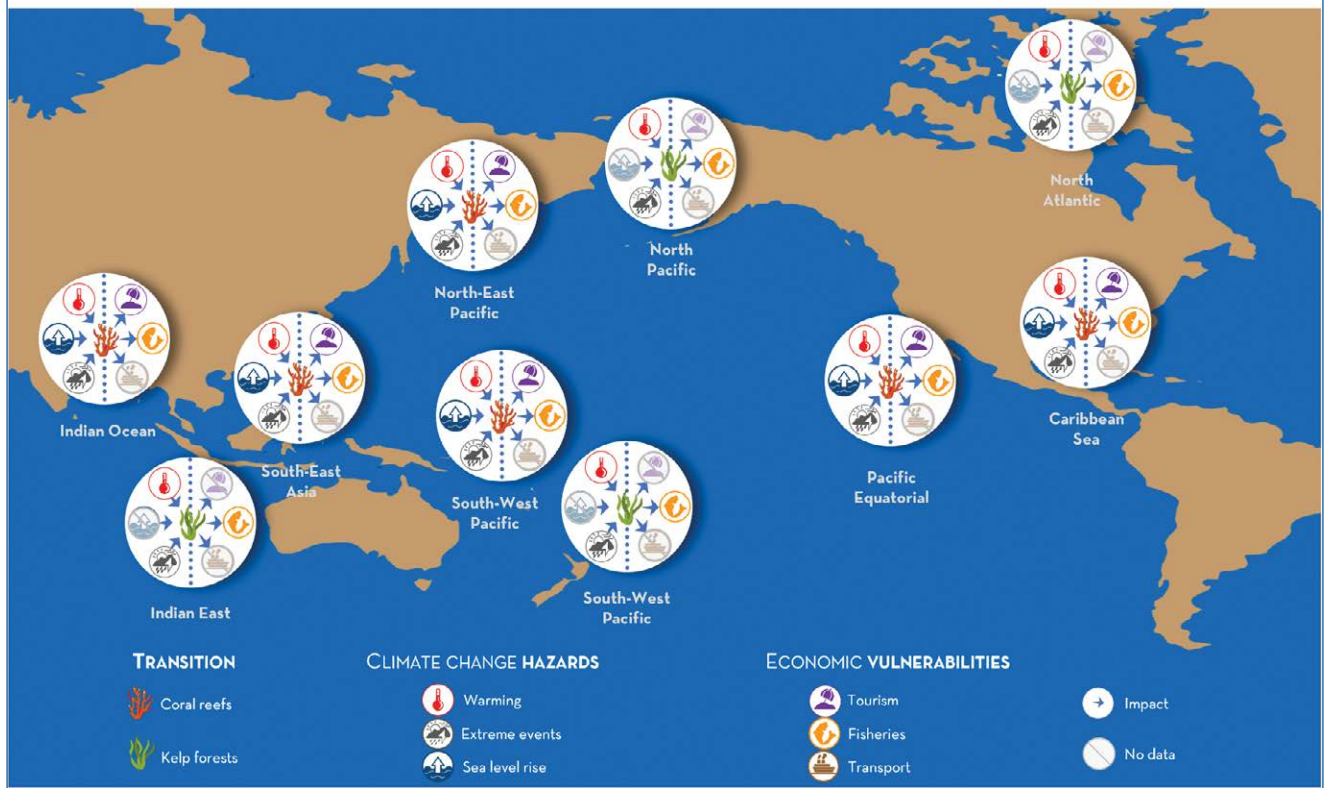

Schematic adapted from the IPCC " Global map with examples of tipping points that have been passed in ocean systems around the world"

Changes in the environmental conditions of a system or ecosystem that are too severe may lead them to reach a tipping point. A ***tipping point*** is a threshold beyond which changes within a system or ecosystem happen quickly and abruptly. All over the world coastal foundational species, such as corals and kelp forests, have already reached a threshold. When a tipping point has been passed the consequences are often lasting and irreversible. Ocean warming and more frequent marine heatwaves have already caused mass mortality events in certain ecosystems. Original populations die-off and are replaced by ***opportunist species*** such as lionfish, sea urchins, and jellyfish.

According to the IPCC, in the scenario of a temperature rise beyond 2°C by 2100, the **"risks of extirpation, extinction and ecosystem collapse escalate rapidly"**. A case in hand is warm-water coral reefs, 99% of which would disappear with a warming of 2°C. In the case of warming beyond 5.2°C, "mass extinction of marine species may occur".

FIGURE 3: MARINE HEATWAVES ARE AFFECTING MARINE LIFE AND HUMAN COMMUNITIES

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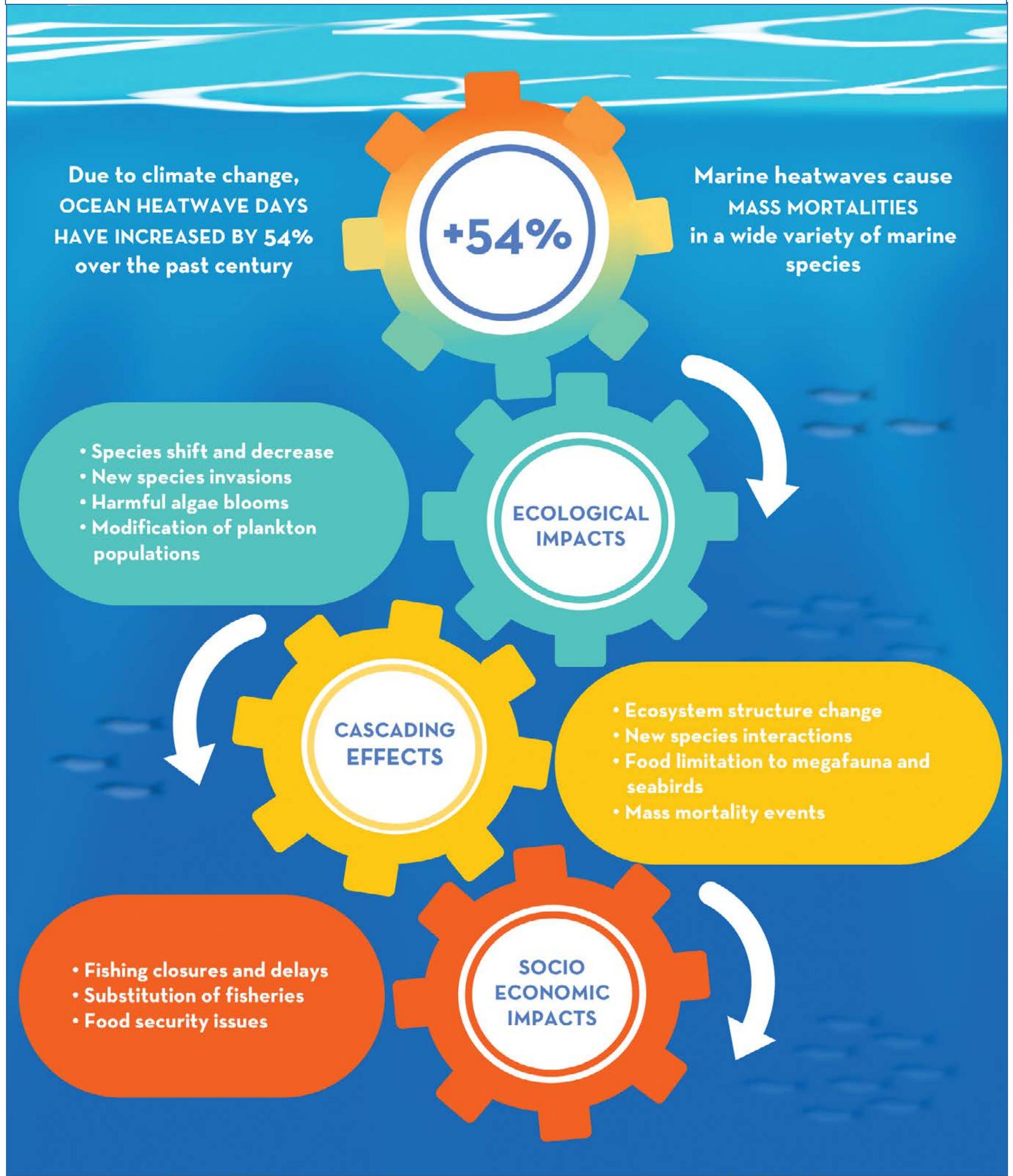


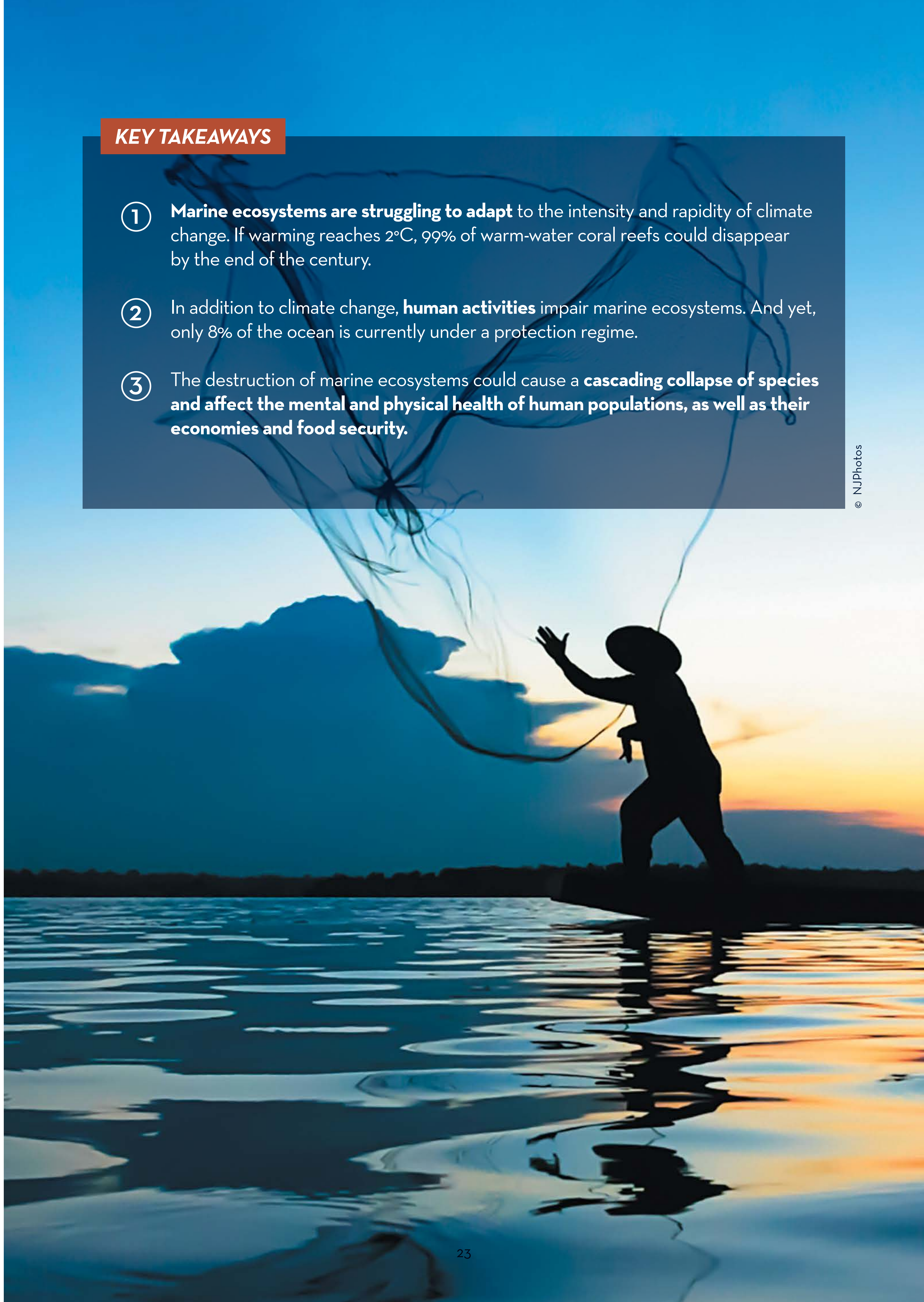
Infographic adapted from the IPCC "Impact pathway of a massive extreme marine heatwave, the northwest Pacific 'Blob', from causal mechanisms to initial effects, resulting nonlinear effects and the consequent impacts for humans"

3 THE CONSEQUENCES OF ECOSYSTEM DEGRADATION ON HUMAN SOCIETIES

Climate change affects the services provided by marine ecosystems to human societies, whose lifestyles are already being impacted. Thus, coastal populations are increasingly vulnerable to extreme weather events as ecosystems, such as salt marshes or sand dunes, become degraded. Habitat destruction, migration and death associated with these events deteriorate the mental and physical health of populations.

While the impacts are global in nature, levels of ***vulnerability*** differ across the world. Geographical location, income level and wealth, gender, age, type of employment and political context all influence a given population's capacity to adapt. Certain populations, such as fishing communities, are particularly affected by the decline of ecosystems. In tropical regions more than a billion people depend on fishing for employment and food. A collapse in marine resources would directly imperil their economy and food security. Likewise, coastal and maritime industries such as tourism, trade and shipping will be impacted.

Closely linked to that of ecosystems, the ***adaptation capacity of human populations*** relies on the intensity and speed of climatic and oceanic changes. The future vulnerability of marine life and human societies greatly depends on the implementation of mitigation and adaptation measures that take into account marine ecosystems. Such actions must be deployed immediately and across all scales.



KEY TAKEAWAYS

1. **Marine ecosystems are struggling to adapt** to the intensity and rapidity of climate change. If warming reaches 2°C, 99% of warm-water coral reefs could disappear by the end of the century.

2. In addition to climate change, **human activities** impair marine ecosystems. And yet, only 8% of the ocean is currently under a protection regime.

3. The destruction of marine ecosystems could cause a **cascading collapse of species and affect the mental and physical health of human populations, as well as their economies and food security.**

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HOW CAN THE PROTECTION OF MARINE ECOSYSTEMS HELP US ACHIEVE A SUSTAINABLE FUTURE?

1 PROTECTING MARINE ECOSYSTEMS FOR CLIMATE CHANGE MITIGATION AND ADAPTATION

The IPCC highlights a range of solutions for the adaptation of ecosystems and human communities. These include marine ***Nature-based Solutions (NbS)***: which consist of actions designed to protect, restore and sustainably manage marine ecosystems to better prepare nature and populations for the impacts of climate change. The IPCC identifies three types of marine Nature-based Solutions:

- **Marine Protected Areas (MPA)**
- **Ecological restoration**
- **Sustainable fisheries**

Marine Protected Areas are geographical spaces subject to a protection regime with the objective to conserve the biodiversity they contain. The higher the level of protection is, the more human activities are restricted or even prohibited, and the greater the ***ecological benefits***. In light of this, scientific and political recommendations are calling for the protection of at least 30% of marine and terrestrial areas by 2030[1]. However, estimates published in 2021 indicated that MPAs covered less than 8% of the ocean and less than 3% being in high or full protection.

Their distribution is also very uneven. While protected areas are mostly located in coastal zones, the areas outside national jurisdictions – the high seas – are hardly protected at all.

Given the impacts of climate change, MPA design and management must also be reconsidered. Indeed, as conditions change in the ocean, many species could migrate outside of protected areas. Several avenues for reflection have been proposed in order to better accommodate climate impacts, such as extending the area covered, strengthening protection standards, or establishing networks of MPAs.

1/ In 2022, the States Parties meeting in Montreal for the 15th United Nations Convention on Biological Diversity (CBD) adopted the "Kunming-Montreal Global Biodiversity Framework" which included twenty-three goals to be achieved by 2030 if we are to stem the loss of biodiversity and restore natural ecosystems. Under this convention, the States committed themselves to protecting 30% of land, coastal areas, oceans and inland waters by 2030.

Ecological restoration refers to operations intended to assist the regeneration of ecosystems which have been degraded or destroyed. Replanting mangroves or rehabilitating salt marshes, while limiting new activities and settlements in coastal areas are some examples of ecological restoration. However, sea level rise, extreme weather events, and marine heatwaves are all making ecosystem restoration increasingly difficult. In response, methods such as the transplantation of warm-tolerant species, and technical solutions such as genetic manipulation are emerging. Such approaches require strict supervision to ensure they do not harm already vulnerable ecosystems.

As it offers numerous co-benefits, blue carbon ecosystem restoration is often promoted for climate change mitigation and adaptation. It is one of the Carbon Dioxide Removal techniques described by the IPCC.

FOCUS

OCEAN-BASED CARBON DIOXIDE REMOVAL (CDR)

What is ocean-based carbon dioxide removal?

Carbon Dioxide Removal technologies, commonly referred to as CDR, refer to human interventions intended to remove residual greenhouse gases in the atmosphere by storing them durably in reservoirs located, for example, at the bottom of the ocean floor. There is a wide and varied spectrum of such techniques. The IPCC mentions the restoration of blue carbon ecosystems as well as measures known as ***geoengineering***. The latter involves technological interventions, including the ***fertilisation*** and ***alkalinisation*** of the ocean.

Are they sustainable solutions to climate change?

The durability of CDR varies from one technique to the next and is thoroughly debated within the scientific community. The IPCC suggests that Nature-based Solutions, in addition to being cheaper and easier to implement, are more effective and sustainable. Their capacity to absorb CO_2 and maintain favourable conditions for the development of biodiversity and populations has been proven. However, restoration cannot replace the conservation of existing blue carbon ecosystems, as their deterioration constitutes a major risk of CO_2 release. For example, a degraded mangrove would release into the atmosphere part of the carbon stored in its root system.

Geoengineering methods face serious limitations. Their effectiveness in absorbing CO_2 remains unclear as they are still at an early stage of development, and such processes have never been deployed on a grand scale. Critical knowledge gaps remain on their potential impact in terms of greenhouse gases emissions and consequences for biodiversity. A precautionary approach is thus called for and the reduction of greenhouse gases on a global scale remains the priority.

The sustainable management of fisheries contributes to better protecting species from the consequences of fishing and climate change, and safeguards the livelihoods of communities that depend on them. To limit the impact of fishing on exploited resources, certain conventional measures can be deployed. Fixing quotas in line with scientific recommendations, increasing the mesh size of nets and raising minimum catch sizes can contribute to protecting juvenile fish and increasing the abundance of fish populations. Many scientists are calling for the adoption of an ***ecosystem approach*** to fishing. This would require the development of fishing techniques which are less destructive and more mindful of the ecosystem's functioning. It includes banning bottom trawling and electric pulse fishing, as well as restricting access to certain zones (see MPAs). At the same time, it is essential to support the transition of economic activities and populations which depend on fishing. Their adaptation can be supported by facilitating their reconversion to other employment sectors and diversifying the species of fish caught, especially as some of them migrate due to modifications in water temperature and pH.

While marine Nature-based Solutions alone are not sufficient to contain climate risks such as sea level rise, they can be combined with other approaches. Indeed, Nature-based Solutions are not one-size-fits-all solutions that can address the multiplicity of future issues and needs. For example, some coastal cities like New York, Dakar and Marseille have very little space available for replanting operations. To protect the coast from rising sea levels, several cities are combining so-called "hard protections", such as sea walls, with Nature-based Solutions to leverage the many co-benefits they provide.

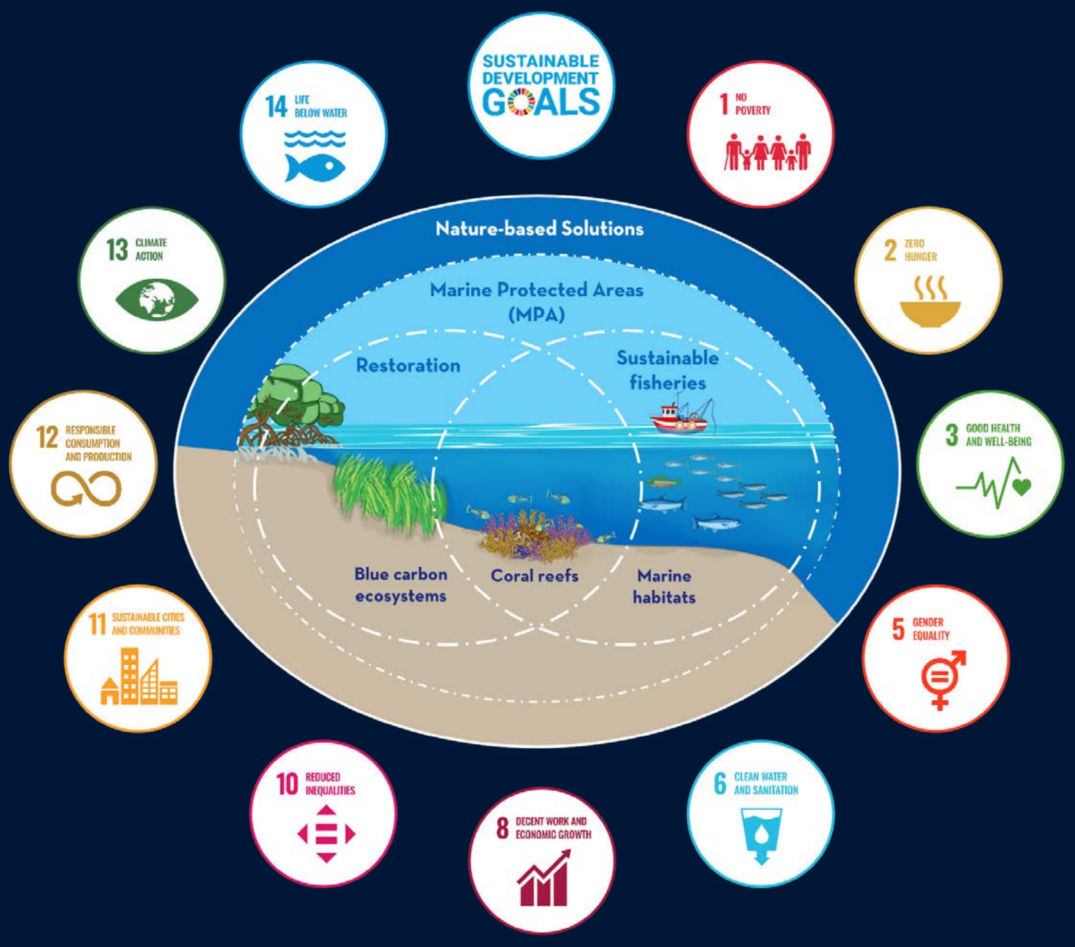
→ Learn more about adapting to sea level rise: *6th IPCC Report: Sea Level Rise, Impacts and Vulnerabilities*

FOCUS

THE CONTRIBUTION OF MARINE ECOSYSTEMS TO THE SUSTAINABLE DEVELOPMENT GOALS (SDGS)

Adopted by the United Nations in 2015, the ***Sustainable Development Goals (SDGs)*** propose a global framework for shaping a sustainable future. Numbered from one to seventeen, they formulate a response to the global challenges facing humanity, notably issues related to poverty, inequality, climate change, the environment, prosperity, peace and justice. These goals are interconnected and if each one of them is achieved, the entire planet will result in better living conditions.

FIGURE 4: ACHIEVING THE SUSTAINABLE DEVELOPMENT GOALS THANKS TO MARINE NATURE-BASED SOLUTIONS



Schematic adapted from the IPCC "Contributions of nature-based solutions (NbS) in the oceans to the Sustainable Development Goals."

Through the protection of Life Below Water (SDG14), Nature-based Solutions contribute to maintaining fisheries and therefore to achieving the SDGs No Poverty (SDG1), Zero Hunger (SDG2), and Good Health and Well-Being (SDG3). In addition, including citizens and ensuring greater representation of women in the management of ecosystems helps bring about Reduced Inequalities (SDG11) and Gender Equality (SDG5). Nature-based Solutions also support Climate Action (SDG13) by increasing the capacity of ecosystems to capture and store carbon, and by encouraging better approaches to managing the maritime zone, conducive to the development of Affordable and Clean Energy (SDG7).

2 THE NECESSARY CONDITIONS FOR THE SUSTAINABLE CONSERVATION OF MARINE ECOSYSTEMS

As greenhouse gases emissions continue to increase, the impacts of climate change on ecosystems intensify, diminishing the latter's capacity to provide co-benefits. Hence why **drastically reducing our greenhouse gases emissions is vital for marine ecosystems.** Greenhouse gases could be significantly reduced by decarbonising the largest emitting industries, such as energy and transport.

FOCUS

REDUCING OUR GREENHOUSE GASES EMISSIONS: THE TRANSITION OF THE MARITIME SECTOR AS A SOURCE OF SOLUTIONS

The IPCC highlights several avenues to reduce greenhouse gases emissions, including the transition of the maritime sector. Innovative and low-carbon technologies have advanced rapidly in these industries.

Decarbonising shipping

Maritime transport emits 2 to 3% of all emissions from human activities. In order to reduce these emissions, the sector's transition to low-carbon fuels such as hydrogen, ammonia, biofuels and other synthetic fuels is being considered. **Electrification** is also put forth for short trips and to reduce emissions from port operations. The IPCC underscores **simple and cost-effective solution**s such as reducing speed and restricting the trips of partially loaded vessels.

Developing Marine Renewable Energies (MRE)

The ocean offers many opportunities for the development of renewable energies. Marine energy can be harnessed from tides, waves, thermal energy conversion, currents, salinity gradients and offshore winds. While their development encounters economic obstacles and raises doubts as to their potential impact on biodiversity, these energy sources are nevertheless reliable, predictable and very consistent. Reallocating subsidies from fossil fuels to marine renewables would help finance the research required for their scaling-up.

Reducing all stressors from human activities in the global ocean is a prerequisite to ensure ecosystems remain ***resilient*** to the impacts of climate change and concurrently act as effective adaptation and mitigation solutions. MPAs, low-impact fishing methods, and pollution reduction strategies (plastic waste, sewage, pesticides, noise pollution) are all essential to reduce the impact of human activities. In the deep sea, given the environmental risks associated with potential exploitation projects, additional scientific research, monitoring and assessments are a precondition.

In the medium term, socio-institutional levers are central to reduce the impact of climate change on the ocean and coastal ecosystems. As such, to guarantee that adaptation measures are fair and meet local needs, governance overhauls are necessary. Such changes ought to ensure compliance with human rights, improve the transparency of public policy-making, and enhance the participation of diverse communities in the decision-making process. An additional challenge lies in increasing and ensuring fair and equitable access to the financial resources required to implement mitigation and adaptation responses. Better informing and educating populations about climate risks and ecosystem loss is also crucial to initiate shifts in individual and collective behaviours.

Finally, given that the impacts of climate change are already affecting many communities and transcend borders, international cooperation is an indispensable lever for climate action. Rallying states and non-state actors around common climate goals is essential to carry out mitigation and adaptation policies that meet the current challenges.

KEY TAKEAWAYS

1. The IPCC identifies three types of marine Nature-based Solutions: **Marine Protected Areas, ecosystem conservation and restoration, and sustainable fisheries management.**

2. Marine Nature-based Solutions can contribute to the **mitigation, adaptation and sustainable development** of societies but their effectiveness depends on the drastic **reduction of greenhouse gases emissions and human stressors** on ecosystems.

3. Essential levers for action include **fairer and more inclusive governance, better allocation of financial resources, and greater international cooperation.**

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CONCLUSION

- The ocean is central to the regulation of the climate system.
- It is home to a great diversity of ecosystems present at all depths and throughout the world.
- These ecosystems convene a multitude of different species and provide numerous services to human societies.
- As climate change accelerates and intensifies, and human-induced pressures increase, certain marine ecosystems are reaching their tipping points.
- Ecosystem degradation in turn accelerates climate change and increases the vulnerability of human populations.
- In contrast, protected and healthy ecosystems are more resilient and provide solutions to the challenges of climate change.
- Nature-based Solutions can generate multiple co-benefits in terms of mitigation and adaptation, and contribute to achieving the Sustainable Development Goals.
- Their effectiveness depends on reducing greenhouse gases emissions and mitigating the impacts of human activities. Institutional, political and financial resolve is a precondition to the deployment and sustainability of Nature-based Solutions.

Glossary

Adaptation Population and ecosystems adjustments to climate change and its impacts. For humans, this involves measures to reduce their vulnerability to risks (population displacement, diversification of fisheries, etc.). Certain living organisms adapt to alterations in their environment by undergoing genetic change or by moving to a new habitat.

Alkalinisation Increase of the pH value of the ocean through the addition of alkaline substances (carbonate or silicate rocks) naturally found in seawater. The term refers to an artificial technique to quell ocean acidification caused by human activities.

Benthic Refers to the bottom of the sea. Describes an organism which lives on or in close proximity to the ocean floor.

Blue carbon (ecosystem) Ecosystem recognised for its considerable capacity to capture and sequestrate carbon, in addition to many other benefits (marine living resources, reproduction and nursery ground, wave energy mitigation, erosion control). Damaged or destroyed, these ecosystems can release vast quantities of carbon into the atmosphere. Mangroves, salt marshes and seagrass beds are classified as blue carbon ecosystems by the IPCC.

Carbon Dioxide Removal (CDR) Human intervention to remove residual greenhouse gases from the atmosphere by durably storing them in reservoirs situated, for example, at the bottom of the ocean.

Dead zone Also called hypoxic zone, it refers to areas of shallow-water ocean and freshwater environments where oxygen levels have fallen so low as to prevent the survival of aerobic organisms (i.e., that need oxygen to produce their energy).

Ecological benefit Positive effect that healthy ecosystems have on the environment or human societies, or both.

Ecosystem System comprising a group of living organisms, a physical environment and their interactions. The boundaries of an ecosystem are more or less indistinct and can change over time. Ecosystems connect and overlap to such an extent that their size can vary from the very small to all living organisms on the planet (biosphere). In the current era, most ecosystems contain people, either as key organisms or due to the influence their activities have on the environment.

Ecosystem approach Method of managing land, water and living resources which takes into account ecosystems' functioning to promote the conservation and sustainable use of natural resources. Its primary goals are the conservation of biodiversity and the way ecosystems are structured and function in order to maintain ecosystem services.

Fertilisation Human intervention to stimulate the photosynthesis of phytoplankton as a means to store carbon in the sea. This method involves adding nutrients such as iron to the sea to stimulate the capacity of phytoplankton to capture CO_2 thus increasing the amount of carbon stored in the ocean.

Geoengineering A broad set of methods and technologies aimed at altering environmental conditions in order to mitigate or compensate for the impacts of climate change. These techniques deployed at small or large scale, use and affect the climate system, including the atmosphere or the ocean. As a result, they could have negative and unintended effects that cross national boundaries.

Greenhouse gases (GHG) Gaseous constituents of the atmosphere, capable of partially absorbing the sun's heat at the earth's surface. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the principal GHGs in the atmosphere. The increasing concentration of GHGs in the atmosphere is for the most part attributable to human activities, causing a rise in temperatures.

Land-use change May designate a change in land use, such as a mangrove forest turned into agricultural land or building plots. May also indicate a shift in land management, such as a variation in the level of legal protection afforded to ecosystems.

Methane hydrate Solid compound resulting from the crystallisation of water and methane mix. Methane hydrates occur as ice on the seafloor, mainly on continental shelves and margins.

Mitigation Human intervention to curb emissions or enhance carbon sequestration.

Nature-based Solution (NBS) Any and all actions designed to protect, restore and manage marine ecosystems in a sustainable way in order to better prepare nature and populations for the effects of climate change.

Nutrient Nutrients are essential compounds found in food or in nature. Living organisms use them to ensure their existence, growth and reproduction.

Ocean acidification Reduction in the pH value of the ocean caused by higher concentrations of CO_2 in the water.

Opportunist species Species that derive benefits from its environment in all circumstances, capable of adapting to various conditions.

Pelagic The pelagic zone comprises the entire water column of the open ocean, from the surface to the sea floor. The term also describes the organisms living in this zone.

Plankton Floating microscopic animals (zooplankton) and plants (phytoplankton) that live in aquatic environments. These organisms do not have the ability to swim against the currents which, as a result, control their distribution and migration.

Primary production All the organic matter in an ecosystem produced by plants and microbes through photosynthesis, using light and CO_2 as sources of energy and carbon. It can also be produced through chemosynthesis, using chemical energy such as is found in deep-sea hydrothermal vents.

Resilience Capacity of human or natural systems to cope or reorganise in the face of events or disruptions in order to maintain their essential functions, identities and structures.

Salt marsh Coastal wetlands flooded with seawater at high tide. Mostly situated in high and medium latitudes, salt marshes provide numerous ecosystem services, such as habitat and shelter for marine species, wave-energy mitigation, sediment retention, rainwater absorption, and water filtration.

Stratification Forming processes of layers of ocean water with different properties (salinity, density, temperature) which act as barriers for water mixing. Stratification increases as the ocean warms, usually resulting in an increase in temperature at the surface, a reduction of oxygen in deeper waters, and an acidification of the upper ocean.

Sustainable Development Goal (SDG) The seventeen Sustainable Development Goals (SDGs) were adopted by the United Nations in 2015. They are a call to action to eradicate poverty, protect the planet, and make sure that all humans live in peace and prosperity by 2030. They cover all the defining issues of our time, such as climate, biodiversity, energy, water, poverty, gender equality, economic prosperity, peace, agriculture and education.

Tipping point A level of change in system properties beyond which it reorganises, often abruptly and rapidly. Once this threshold has been reached the consequences become long-lasting and often irreversible, even if the causes are eliminated.

Upwelling system A region of the ocean where cold, typically nutrient-rich waters well-up from the deep ocean to the surface.

Vulnerability Propensity or predisposition to be adversely affected by climate change depending on a variety of factors.

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