FISHING AND AQUACULTURE IN A CHANGING CLIMATE: CHALLENGES AND PERSPECTIVES

OCEAN & CLIMATE
PLATFORM

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About the Ocean & Climate Platform

OCEAN & CLIMATE PLATFORM

The Ocean & Climate Platform (OCP) is dedicated to fostering dialogue and collaboration between the scientific community, civil society, and policymakers. It unites over 100 global organisations—including research institutes, NGOs, foundations, scientific and educational centres, businesses, and local authorities—to promote scientific knowledge and advocate for ocean-based solutions in the fight against climate change. As a leading voice in the ocean-climate community, the OCP holds observer status at key UN conventions on climate (UNFCCC) and biodiversity (CBD) and participates in the French governmental review of IPCC reports. The OCP's efforts are also fully aligned with the United Nations Decade of Ocean Science for Sustainable Development (2021-2030).

Sharing ocean knowledge from major scientific reports

Since 2018, the OCP has leveraged its network of scientists and experts of science communication to contribute to the French governmental review of ocean-related chapters in IPCC reports. This involvement has included the review of the 1.5°C Report (2018), the Special Report on the Ocean and Cryosphere (2019), and the Sixth Assessment Report (2021-2023). To amplify and facilitate the understanding of the ocean-climate-biodiversity interactions highlighted in these reports, the OCP collaborates with a community of science communication experts to produce accessible content tailored to decision-makers and the general public. In 2019, it published "Ocean and Climate: New Challenges," based on the Special Report on the Ocean and Cryosphere, and in 2023, "What Ocean for Tomorrow? Marine Ecosystems in a Changing Climate – Insights from the IPCC Sixth Assessment Report," providing a comprehensive overview of how marine ecosystems, climate change, and sustainable development intersect, as informed by the latest scientific findings.

Pursuing this work, in 2024, the OCP releases "Fishing and Aquaculture in a Changing Climate: Challenges and Perspectives," a synthesis of insights drawn from recent reports by the Intergovernmental Panel on Climate Change (IPCC), the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), the Food and Agriculture Organization (FAO), and the World Ocean Assessment (WOA). This report aims to provide a clear and up-to-date understanding of the challenges and opportunities for fisheries and aquaculture in a changing climate.

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Introduction

Climate change is disrupting ocean conditions. At sea as on land the consequences are profound for marine ecosystems and the societies that depend on them. In this changing climate, the sectors of fishing and marine aquaculture are on the front line.

In addition to providing employment and income for nearly 62 million people across the globe, these activities are key to ensuring global food security. Aquatic resources account for 20% of the daily animal protein intake for more than 3 billion people worldwide.

Total fisheries production has been steadily increasing since the 1950s. For many years, fishing accounted for a major part of this production but catches have stagnated since the late 1980s, whereas marine aquaculture has risen significantly. In 2022, for the first time in history, aquaculture overtook wild-caught fishing as the main source of aquatic animal production.

This growth has direct consequences for fish populations and their environments. The science is clear: according to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) fishing has been the human activity with the greatest impact on marine biodiversity for the last fifty years. The primary reasons include excessive fishing volumes, coupled with the use of non-selective techniques and gear that severely impacts ecosystems. Similarly, the rapid expansion of marine aquaculture often leads to the destruction of natural habitats, pollution risks, disease outbreaks, and competition between farmed and wild species.

The vicious circle perpetuated by fishing and aquaculture is all the more exacerbated by climate change. The spatial distribution of species is changing, while some fish populations are locally collapsing. Certain regions, activities, and human populations are particularly vulnerable to these upheavals. ***Small-scale fisheries***, and indigenous and local communities living on the coasts, especially in developing countries and island states, are heavily reliant on marine resources for their food and livelihoods.

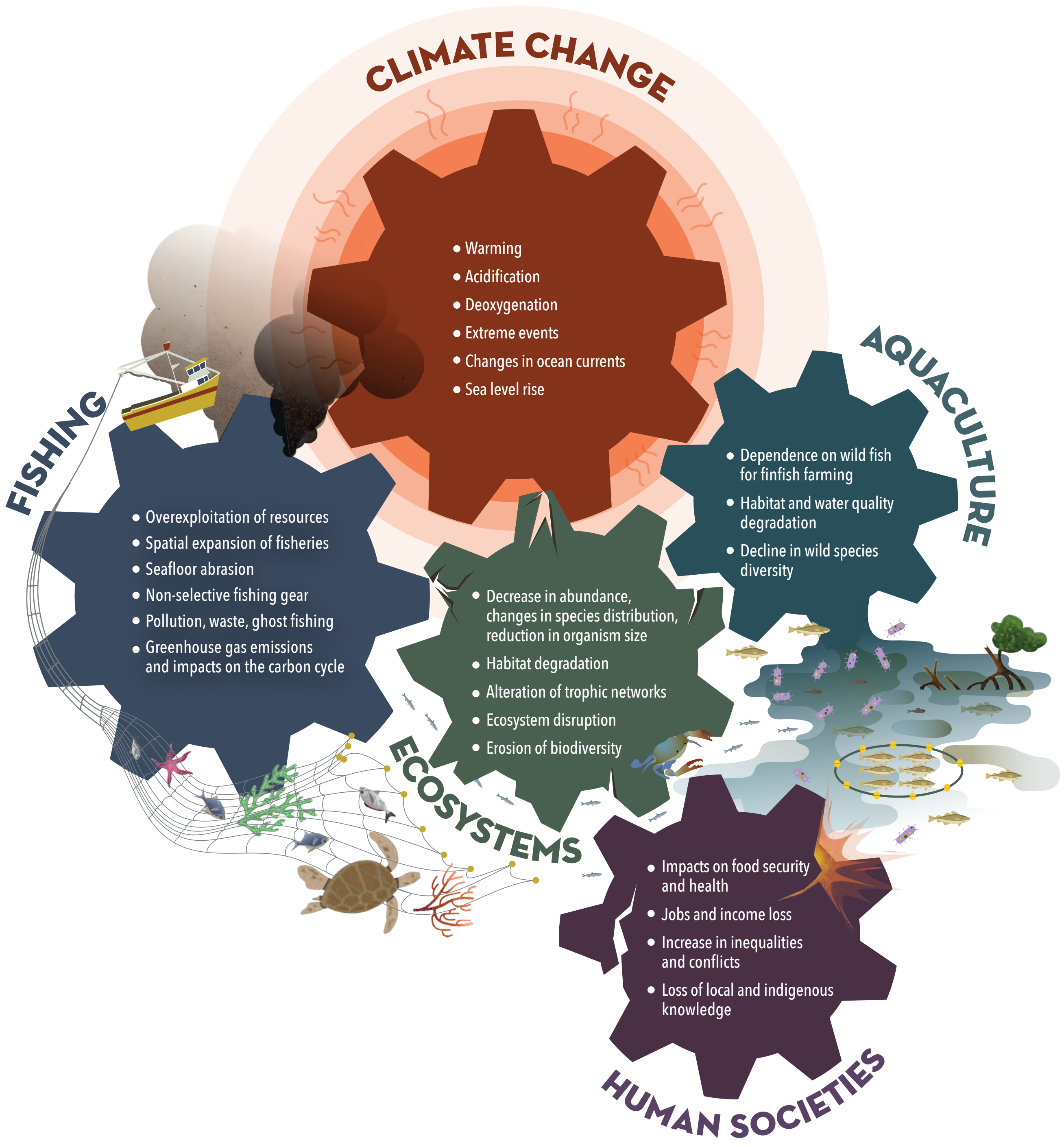
In the current context of climate change, it is urgent to support the transition of fishing and aquaculture practices towards a virtuous model that is more sustainable for marine life and desirable for societies.

In view of these issues, the Ocean & Climate Platform has published **"Fishing and Aquaculture in a Changing Climate: Challenges and Prospects".** Drawing on the findings of the latest reports of the Intergovernmental Panel on Climate Change (IPCC), the IPBES, the United Nations Food and Agriculture Organization (FAO), and the World Ocean Assessment, this publication addresses the following questions:

- **What are the impacts of climate change on fishing and marine aquaculture?**
- **How do the fishing and aquaculture sectors affect marine ecosystems?**
- **What are the consequences for human societies?**
- **What adaptation solutions need to be implemented for these sectors?**
- **How to strengthen the resilience of ecosystems and societies to the effects of climate change?**

FISHING AND AQUACULTURE IN A CHANGING CLIMATE: CHALLENGES AND PERSPECTIVES

Fishing and aquaculture practices greatly destabilise ecosystems, undermining these activities and the populations that rely on them. Climate change further exacerbates these impacts, making the fishing and aquaculture sectors even more vulnerable.



Collectively defining a sustainable and desirable future for fishing and aquaculture is essential to mitigate climate change and strengthen the resilience of ecosystems and human societies.

CLIMATE CHANGE IMPACTS FISHING AND AQUACULTURE

1 CONDITIONS FOR LIFE IN THE OCEAN ARE CHANGING

Increasing greenhouse gas emissions and a warming atmosphere are altering the characteristics of the ocean (temperature, oxygen, salinity, pH, etc.). These changes disrupt its functioning and the environmental conditions essential for marine life. The sectors which depend on the ocean, especially fishing and aquaculture, are significantly impacted.

The ocean becomes ***more acidic***. as carbon dioxide (CO_2) levels in the atmosphere increase. Above a certain level of CO_2 dissolved in water, the development and growth of organisms with shells and other calcareous structures are affected.

The warming of the atmosphere raises ocean water temperature, causing considerable alteration in the physical and chemical conditions:

- Marine currents are changing and waters are becoming ***stratified***, disrupting ***nutrient*** cycles, particularly in ***upwelling systems*** which are the most productive fishing areas in the world.
- Global deoxygenation affects fish physiology and behaviour. The expansion of oxygen-poor areas reduces the availability of habitats and alters ***trophic networks***, such as in the Baltic Sea where zones of minimal oxygen have restricted spawning grounds for cod.
- **Extreme climate events** are intensifying and becoming more frequent, sometimes with irreversible consequences on the abundance and spatial distribution of fished species. For example, the number of days of ***marine heatwaves*** has increased by 54% over the past century, causing mass mortality events for numerous species.
- **Rising sea levels** increase the frequency and intensity of marine submersions, contributing to the loss of coastal habitats, such as mangroves and seagrass beds that play a major ecological role. These phenomena also threaten aquaculture sites and port infrastructures.

2 FROM FISH TO ECOSYSTEMS: CASCADING IMPACTS

Changes in the ocean have cumulative effects that impact all levels of marine life, on which fishing and aquaculture depend.

POPULATIONS ARE COLLAPSING AND SPECIES ARE REDISTRIBUTING

Climate change is causing local collapse of populations of fish, molluscs, crustaceans and algae, whereas other populations are expanding outside their usual range. For example, cod populations in the Celtic and North Seas are drastically declining, whereas they are increasing north of Norway. In the northern hemisphere these shifts are driving species redistribution towards the poles.

Changing oceanic conditions also affect the physiology and biology of organisms, with consequences on their reproduction and growth. From 2013 to 2016 a prolonged marine heatwave, commonly known as the “Blob” struck the eastern Pacific coast, resulting in declines in fish and invertebrate populations as well as genetic and/or physiological modifications, such as a reduction in size and nutritional value.

DEGRADED NATURAL HABITATS

Climate change affects marine habitats such as coral reefs, mangroves, seaweed fields, and seagrass meadows, which play a vital role in species reproduction, development and their interaction. These hotspots of marine biodiversity are particularly vulnerable. In a global warming scenario of +2 °C, 99% of the world’s coral reefs could disappear by the end of the century, despite being home to 30% of marine biodiversity.

RIPPLE EFFECTS THROUGH TROPHIC NETWORKS

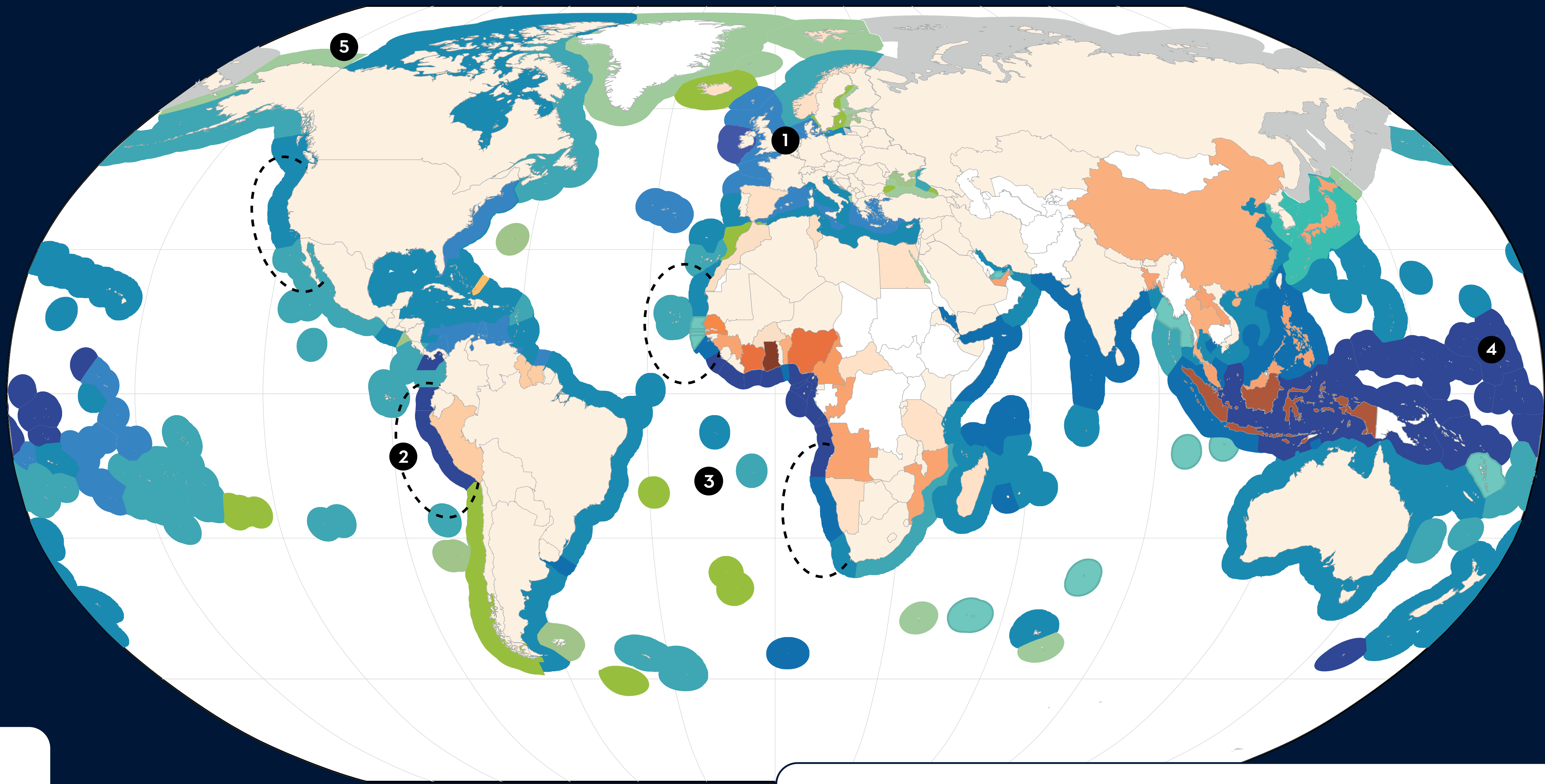
Through trophic networks, all life in the sea and on land is being disrupted. Plankton, the foundation of all marine food chains, is experiencing shifts in abundance, distribution and composition. All trophic levels are concerned, including the apex predators, such as large fish, mammals and seabirds. Globally, declines in ***primary production*** and in the efficiency of energy transfers between prey and predators is causing a reduction in overall marine life abundance. Meanwhile, warming temperatures in the ocean accelerate sea ice and permafrost thaw, intensifying the release and concentration of contaminants such as mercury. Instead of being eliminated, these contaminants accumulate along the food chain to end up within the organisms of top predators. This poses grave risks for food safety and human health.

INCREASINGLY UNSTABLE ECOSYSTEMS

The compound impacts of climate change and biodiversity loss are destabilising marine ecosystems. For example:

- ***Invasive alien species*** are competing with native species for food and habitats, significantly modifying ecosystems.
- Key marine biological cycles are shifting, such as ***phytoplankton blooms***. The timing of these crucial life-history events in marine trophic webs is occurring earlier in the season, disrupting the life cycle of many species.

VULNERABILITY OF POPULATIONS TO FUTURE CLIMATE CHANGE IMPACTS ON FISHERIES PRODUCTIVITY



Upwelling Zones

Change (in percentage) in fishery productivity within Exclusive Economic Zones by 2100 (RCP 8.5*)

-50 -30 -15 -10 -5 0 5 10 No data

*IPCC scenario where greenhouse gas concentrations continue to increase at current rates.

Current share (in percentage) of fish in animal-based diets

0 5 10 15 20 25 30 35 40 45 50

Climate change and fishing pressures on biodiversity and ecosystems vary across the world:

1. Semi-enclosed and continental seas host numerous human activities, whose impacts on resources are exacerbated by climate change.
2. Climate change alters currents and oxygen levels in coastal upwelling zones, affecting primary productivity and shrinking available habitats for species.
3. As coastal resources decrease, industrial high-seas fishing is expanding, targeting large predator and migratory species.
4. Rising temperatures in tropical areas are expected to lead to the largest global decline in fish catches. Small Island Developing States are particularly vulnerable, with fish resources accounting for 50% of their daily animal protein intake
5. Fishing activities are expanding towards the Arctic as glaciers are melting and the distribution range of species is shifting.

Infographics adapted from Figure 5.21 in Chapter 5 "Changing Ocean, Marine Ecosystems, and Dependent Communities" of the IPCC SROCC (2019), and from the map "Dimensions of agriculture and marine fisheries vulnerability to climate change, B. Change in fisheries productivity by 2100 (exposure; RCP8.5)," from the paper "Escaping the perfect storm of simultaneous climate change impacts on agriculture and marine fisheries" (2019).

THE COMBINED IMPACTS OF CLIMATE CHANGE AND FISHING AROUND THE WORLD

On a global scale the pressures exerted by climate change and fishing on biodiversity and ecosystems are changing and vary from one region to another.

Continental and semi-enclosed seas are major fishing grounds, but the abundance and diversity of species is declining due to the compound effects of climate change and the multiple pressures of human activities. This is evident in the Celtic and North Seas where the productivity and yield of fisheries has largely declined.

Coastal upwelling zones, although covering only 1% of the ocean's surface, are home to the world's most productive fisheries. Cold nutrient-rich waters welling up to the surface create favourable conditions for marine life. Yet, climate change is altering the intensity and duration of the winds that drive upwellings, ultimately affecting the primary production and entire trophic networks.

In the high-seas, fishing operations are expanding to compensate for the decline in coastal resources. Mainly industrial and undertaken by a few developed nations, high-seas fishing predominantly targets large predatory and migratory species such as tuna.

Tropical zones are projected to experience the sharpest decline in fish catches due to climate change. As temperatures rise, some populations will go extinct, while others will relocate to cooler waters, in particular to polar regions.

Polar regions, especially in the Arctic where glaciers are melting, are becoming increasingly accessible to human activities such as fishing. At the same time, the northward shift of species has allowed the development of one of the world's most productive fisheries. However this trend may not last and biodiversity loss could eventually occur as the acidification of polar seas accelerates.

FISHING AND AQUACULTURE: INCREASING PRESSURE ON FISH AND ECOSYSTEMS

1 FISHING PRACTICES IMPACTING MARINE LIFE

FISH STOCKS ARE BEING DEPLETED TO INCREASINGLY UNSUSTAINABLE LEVELS

The United Nations Food and Agriculture Organization (FAO) estimates that the proportion of overexploited fish stocks has steadily increased over the last decades, rising from 10% in 1974 to nearly 38% in 2021. Currently, close to 50% of fish stocks are fully exploited. These stocks are already under intense pressure, and it is estimated that their biomass has been reduced to a third of what it would be without fishing. The impact of fishing also extends to other non-targeted and sometimes vulnerable species (e.g., mammals, turtles, seabirds), as well as their habitats and trophic networks. In essence, the pressure of fishing disrupts entire marine ecosystems and profoundly alters their structure and functioning.

SOME DESTRUCTIVE FISHING TECHNIQUES AND EQUIPMENT

Industrial fishing which involves vessels over 24 m long, accounts for only a small fraction of the global fleet and workforce, yet it occupies 55% of the ocean's surface, mainly in the North-East Atlantic, North-West Pacific, and the upwelling zones of South America and West Africa. In contrast, small-scale artisanal fisheries, using vessels under 12 m long, accounts for almost 90% of ships and approximately 40% of global fish catches.

The environmental impact of fisheries depends less on vessel size than on the fishing gear and technique used. ***Bottom trawls*** are notorious for being particularly destructive for habitats, plants and animals found on the seabed. These methods are also non-selective, often leading to the catch of large quantities of juveniles and unwanted species which are discarded back into the sea. Longlines, nets and pelagic trawls are also responsible for ***bycatches*** of sensitive species, in particular turtles, mammals and seabirds. It is estimated that nearly 10% of catches are discarded dead at sea. Abandoned or lost fishing gear known as "***ghost fishing***" is responsible for a sizable proportion of total catches.

FISHING PRACTICES CONTRIBUTE TO CLIMATE CHANGE

The sector contributes to global emissions of greenhouse gases. Large vessels, especially bottom trawls, have significant fuel demands, consuming 1 to 2 litres of diesel per kilogram of fish caught. In contrast, lower-impact techniques consume less than 0.5 litres per kilogram of fish landed. Scientists are also working on measuring the impact of fishing on the carbon cycle. Indeed, by disrupting trophic networks, fishing is likely to diminish the efficiency of the ***biological carbon pump*** of the ocean. Certain fishing gears such as bottom trawls, could scrape-off and resuspend the carbon stored in sediments, thereby contributing to rising greenhouse gas emissions.

OTHER HUMAN PRESSURES AT SEA AND ON THE COAST

Fisheries are not the only human activities to exert pressures on the ocean. ***Land-use changes*** in natural coastal and marine areas for urban, industrial, and agricultural development, along with the discharge of pollutants and contaminants (plastics, heavy metals, chemical and agricultural runoffs), extractive activities (mining, gas, oil), and the expansion of sea freight shipping are additional stressors on marine living resources and ecosystems.

2 A LESS PRODUCTIVE FISHERY IN THE FACE OF DIMINISHING RESOURCES

As it disrupts ecosystems, the fishing industry also degrades the ocean's health, upon which it directly depends. Although overfishing has decreased in recent years in the exclusive economic zones of developed countries, particularly in North America and along the Atlantic coast of Europe, the global situation remains dire. Fishing productivity is diminishing, further exacerbated by the accelerating impacts of climate change.

To cope with the depletion of stocks in coastal waters, fishing technologies have been refined, and operations have extended further offshore and into deeper waters. Although conducted by a minority of vessels and countries, high-seas catches have grown from 0.5 million tonnes in 1950 to 4.3 million tonnes in 2014 (see the box on "The combined impacts of climate change and fishing around the world").

Fishing now faces a paradox: despite advancements in capacity and technology, the overall productivity is steadily declining. Global marine fishing production peaked in 1996 at 86 million tonnes of catches. Since then, the sector has been experiencing a slow but continuous decline.

The IPCC warns that if our greenhouse gas emissions continue to rise, "global warming, acidification, and business-as-usual fishing policy [...] are projected to place around 60% of global fisheries at very high risk."

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FOCUS

REGULATING FISHING PRACTICES: THE CASE OF ILLEGAL, UNREPORTED AND UNREGULATED FISHING (IUU FISHING)

The term ***"illegal, unreported and unregulated fishing" (IUU)*** refers to fishing activities undertaken in protected areas, in breach of national, regional and international laws and conventions, as well as the failure to properly report catches. According to the FAO, IUU fishing accounts for 26 million tonnes of fish landed annually, representing a third of all reported catches.

Where is IUU fishing most prevalent?

Certain areas of the ocean are particularly affected by IUU fishing due to insufficient legal protection and enforcement capacity. The high-seas, located beyond national jurisdictions, are particularly exposed; however IUU fishing occurs everywhere, including in coastal waters, involving all types and sizes of vessels and gear.

What are the implications for marine ecosystems?

The impact of IUU fishing is difficult to quantify as, by definition, it involves undisclosed gear usage, catch volume and poor traceability. It exacerbates the overexploitation of stocks and the depletion of resources. The most harmful practices fall under this category, such as mass fishing of juveniles and vulnerable species, as well as destruction caused by methods such as dynamite fishing. As a result, IUU fishing compromises all efforts towards sustainable fishing practices.

How does it relate to climate change?

Climate stressors (temperature, acidity, etc.) and biodiversity loss can push fishers, hitherto working legally, to adopt undeclared or illegal practices in an attempt to compensate for diminishing resources.

What are the consequences for humans and economies?

Inadequate enforcement and regulation facilitate fraud related to seafood products and the perpetuation of forced labour. According to the International Labour Organization, 21 million people are enrolled in forced labour in the fishing and aquaculture sectors. IUU fishing also generates important economic losses, estimated to be between 9 and 17 billion dollars (USD) annually worldwide, from 2005 to 2014.

How is the international community responding?

In 2015, 193 member states of the United Nations (UN) adopted the 2030 Agenda for Sustainable Development which sets 17 ***Sustainable Development Goals (SDGs)***. SDG 14 focuses on marine life and in particular, on eliminating harmful subsidies that encourage IUU fishing by 2020. In 2022 the members of the World Trade Organization (WTO) agreed to ban subsidies that encourage IUU fishing, overfishing, and unregulated fishing in international waters.

3 THE PARADOX OF MARINE AQUACULTURE

According to the FAO, global aquaculture is rapidly expanding and now supplies more fish for human consumption than marine capture fisheries and could account for 60% of the world's fish supply by 2030. Although presented as a sustainable alternative to fishing, marine aquaculture still exerts significant impacts on marine ecosystems, particularly in ***finfish farming***.

MARINE FINFISH FARMING DEPENDS HEAVILY ON WILD FISH STOCKS

Farms rearing carnivorous fish such as salmon, tuna, sea bream and shrimps greatly depend on wild-caught fish. About 70% of their feed comes from external sources, primarily fishmeal and fish oil derived from wild-caught marine organisms such as forage fish and ***krill***. While this dependence is diminishing, in 2016, almost 69% of fishmeal and 75% of fish oil went to aquaculture. In Antarctica, fishing operations nearly doubled between 2017 and 2020, driven by increasing krill catches, a vital species of trophic networks.

AQUACULTURE INFRASTRUCTURES DISRUPT MARINE HABITATS

The construction of fish farms often involves land-use changes of coastal areas, contributing to their degradation. In some cases, wetlands, mangroves and salt marshes - critical feeding, breeding and nursery grounds for many species of fish, molluscs and crustaceans - are turned into aquaculture sites.

INTRODUCTION OF INVASIVE SPECIES

Species selected genetically to satisfy certain criteria for human consumption, can enter into competition and pose a threat to local marine biodiversity. Farmed fish that escape from enclosures may interbreed with wild populations. For example, in August 2023, more than 3,000 genetically modified salmon escaped from a fish farm in Iceland. Such events threaten the genetic integrity of native species and lead to competition for habitat and food.

RISKS OF PATHOGENS AND PARASITES SPREAD

Marine aquaculture is associated with risks of pathogens introduction. The proliferation of parasites such as sea lice on species bred in captivity can also have grave consequences on wild populations, raising concerns about ***biosecurity***, especially in a context of changing climatic conditions.

POLLUTION AND DEGRADED WATER QUALITY

Water quality can be compromised by the use of antibiotic, chemical inputs, and organic wastes generated by aquaculture farms. These discharges contribute to algal blooms and ***eutrophication*** near aquaculture sites, which can lead to mass mortality events among marine organisms.

HUMAN SOCIETIES APPROACHING A *TIPPING POINT*

Across the world, human populations are not equally exposed to the combined impacts of climate change and human activities on marine resources. The importance of aquaculture and fishing sectors as sources of employment, income and food varies widely. Moreover, the capacity of populations to adapt their fishing practices and livelihoods to cope with the impacts of climate change are uneven.

1 ECONOMIC INSTABILITY AND JOB INSECURITY

The impacts of climate change have already triggered important economic shocks in the fishing sector. In a high greenhouse gas emissions scenario, the IPCC projects that, by mid-century, the global potential revenue from fishing could drop by more than 10% compared to 2000, resulting in losses of up to 15 billion dollars. In 2016, a toxic algal bloom off the northwest coast of the United States of America, led to the closure of the razor-shell fishery, which is practised by native and coastal communities for both leisure and sustenance.

The marine aquaculture sector, which has been developing steadily since the 1990s, has experienced considerable growth in Asia and Africa. Concurrently, global production increased from 10 million tonnes in 1990 to more than 70 million tonnes in 2022. However, this sector is no less affected by climate hazards and has already undergone regular shocks.

To offset these economic losses, governments increasingly allocate subsidies to the fishing and aquaculture sectors. China, Japan, the United States of America, Canada, Brazil and the European Union, account for 86% of all subsidies directed to the fishing and aquaculture sectors. In the absence of sustainable management standards and sufficient means to enforce them, these subsidies risk encouraging harmful practices for ecosystems. According to the Organization for Economic Cooperation and Development (OECD), while a growing share of fishing subsidies is directed to "low-risk" measures, more than 30% of the aid allocated between 2018 and 2020 carried a high risk of encouraging unsustainable fishing practices.

The heightened instability in the fishing and aquaculture sectors has direct consequences on the fish industry workforce. Precarious labour conditions particularly affect migrant workers and women, exacerbating their ***vulnerability*** in what is considered to be one of the most dangerous industries in the world. According to the International Labour Organization the lack of social protections and employment contracts compounded by unsanitary and hazardous working conditions are structural issues of the fishing and aquaculture industries.

2 RISKS FOR FOOD SECURITY AND HEALTH

Marine resources are central to the diet of many populations. Decreases in the abundance, availability and nutritional value of these resources pose a serious threat to food security. Indeed, 3.2 billion humans depend on fishing and aquaculture sectors for at least 20% of their daily protein intake. For populations with few nutritional alternatives, the risk of malnutrition is acute. This is the case of Indigenous People who, on average, consume 15 times more seafood than non-Indigenous People of the same country. In many developing states, notably in Central, East and West Africa and the Small Island Developing States, marine resources constituted 50% of animal protein intake in 2017.

Marine resources are essential for health, and are notably used to produce pharmaceuticals. For certain Indigenous communities, the decline of fish species undermines access to critical resources used in traditional medicine. For instance, Arctic communities of the Pacific northwest have relied on the Hooligan fish for at least 5,000 years to treat ailments like stomach pains, colds and skin conditions. The decline of Hooligan fish due to climate change and human pressures, jeopardises their healing practices

3 DISRUPTION OF LIVELIHOODS AND REGIONAL TENSIONS

Faced with abrupt and rapid changes in the ocean, some local and Indigenous communities may be forced to modify their diets and ways of life, leave their employment, abandon their territories, or even migrate. Therefore, the transition of the fishing and aquaculture sectors is crucial for preserving mental health, culture, heritage, knowledge and customs.

In many coastal regions, small-scale fisheries are in definite decline compared to industrial and mechanised ones. As these small-scale fisheries, which provide numerous jobs and are essential to the coastal economy, wane, so too does the vitality of smaller ports and coastal regions. The economic and social fabric of these communities is thus deeply affected.

As climate change drives a global redistribution of fish stocks, and considerable fluctuations in their abundance, conflicts over resource allocation can arise between communities, small and large-scale fisheries, or even between states. Such conflicts are expected to intensify as disparities widen, especially if fishing management regulations are not updated to reflect the evolution of fish stocks and ecosystems. A clear example of this has been observed in Europe where tensions have escalated between states over fishing quotas for mackerel whose distribution has shifted northward due to ocean warming.

ADAPTING THE FISHING AND AQUACULTURE SECTORS TO CLIMATE RISKS

Scientific research has highlighted the evidence of risks and has underscored the need for urgent action to ensure the sustainability of the fishing and aquaculture sectors, safeguard marine biodiversity and support the resilience of populations.

Two types of actions must be pursued head-on:

- ***Mitigation* of greenhouse gas emissions and the reduction of pressures on ecosystems are indispensable.**
- ***Adaptation* of the fishing and aquaculture sectors to climate change is both vital and inevitable.** The only workable solutions are those that consider the diversity of local, environmental, social and economic contexts. They ought to be dynamic and capable of evolving through space and time, in response to ongoing changes. In other words, it is urgent to collectively define the adaptation pathways that will lead to more sustainable and resilient fishing and aquaculture industries.

Solutions are not just technical in nature. They must integrate ecosystems and lead to profound transformations of societies and institutions, backed by science and local and Indigenous knowledge, inclusive and cooperative governance, and endowed with more robust resources and capacities.

1 ADAPTING THE FISHING SECTOR

A sustainable model for fishing is possible. Studies suggest that overfished stocks can recover within ten years with appropriate governance. By 2050, 98% of overexploited stocks could be considered healthy and more resilient to climate change, if reforms were implemented.

ADOPT AN *ECOSYSTEM-BASED APPROACH FOR FISHERIES MANAGEMENT*

What is an ecosystem-based approach?
Through this approach, fishing impacts are not only considered at the scale of individual species but on entire ecosystems. Ecosystem-based fisheries management takes into account the functioning, structure, habitat and interactions within an ecosystem. This management approach entails minimising the impacts of fishing and other human pressures on ecosystems.

Did you know?

Inspired by agroecology, the concept of pesco-ecology is emerging. Pioneered by Didier Gascuel, this approach combines biodiversity conservation goals with sustainable utilisation of resources. It advocates for environment-friendly, socially and ethically responsible fishing practices that support human societies and coastal regions.

How to reduce the impacts of fishing?
Implementing more cautious management standards, lowering fishing quotas, and increasing the legal minimum landing sizes of fish are key strategies. Besides, more selective fishing techniques and less abrasive alternatives for the ocean floor, such as trap or line fishing, should be prioritised over the use of harmful gears like bottom trawls. Increasing the mesh size of fishing nets would also improve the protection of juvenile fish and rebuild fish stocks.

Did you know?

In Norway, fishers have increased the mesh sizes of their nets from 100 mm to 140 mm. The initiative has been so effective, that they voluntarily raised mesh sizes to 170 mm. This demonstrates that fishing volumes can be maintained while minimising damages on ecosystems, notably by targeting older fish rather than juveniles.

Why preserve specific areas from fishing activities?
Nature-based solutions (NbS) are actions aimed at protecting, restoring and sustainably managing ecosystems to better prepare nature and populations to the impacts of climate change. Marine Protected Areas (MPAs), which aim to reduce or even eliminate sources of pressure on marine ecosystems, qualify as NbS. The higher the level of protection, the more human activities such as fishing are restricted, even prohibited, and the greater the ecological benefits. Expanding marine protected areas and reinforcing protection levels, while developing a coherent network of MPAs, is a particularly timely approach considering the exacerbation of climate change impacts.

INTEGRATE CLIMATE CHANGE INTO FISHERIES MANAGEMENT

How to reduce the carbon footprint of fisheries?
It is possible to mitigate the greenhouse gas emissions of the sector by reducing fuel consumption, notably by opting for low-carbon fuels and practices. Restricting the access of bottom trawling to certain areas would also curb the release of carbon stored in sediment.

How to strengthen fisheries' capacity to adapt?
Integrating climate-change adaptation into fisheries primarily entails ensuring they are managed sustainably in order to preserve the health of ecosystems. This also means providing fisheries with sufficient financial, technical, institutional and legal capacities to adjust and respond to climate hazards. ***Climate services*** such as ***early warning systems***, can provide information on variations, such as changes in temperature, oxygen levels, and even the presence of pathogens. They can also guide stakeholders in their efforts to manage risks. Regulations must also be developed and adjusted to ensure these adaptations are sustainable and do not further degrade ecosystems.

Did you know?

The Philippines have developed an application called ISDApp to support fishers in their risk management which broadcasts and sends through messages simplified and localised weather forecasts.

IMPROVE OUR KNOWLEDGE

Why is knowledge central to sustainable fishing?
Gaining a deeper understanding of how ecosystems function and how human activities and climate change impact them is essential to inform the development of fisheries management and to assess the effectiveness of the chosen adaptation pathways. Combining several scientific disciplines (e.g., sociology, economics and ecology) with local and Indigenous knowledge allows for a comprehensive understanding of local vulnerabilities. Sharing and making this knowledge accessible to a broad audience are key to achieving long-term adaptation.

> **Did you know?**
>
> In New Zealand, the Moana Project is combining indigenous knowledge with leading-edge detection and digital modelling technologies to provide fishers with reliable forecasts on oceanic conditions.

What data could be useful?
Mapping vulnerable ecosystems and oceanic seafloors can help determine areas where fishing should be restricted. Studying species behaviour, their seasonality (for example their spawning periods), and their spatial distribution through time could inform fishing operations. Social and economic sciences both have an essential role to play in this regard. By providing crucial information to assess the performance of various fishing practices, they can enrich the dialogue and facilitate the co-creation of solutions alongside all stakeholders involved in the fishing sector.

PROMOTE MULTILATERAL AND INCLUSIVE FISHERIES

Since marine ecosystems extend beyond the boundaries of national jurisdictions, to «think locally, we must act globally». Protecting them requires coherent management principles and standards across states. International, regional and local cooperation is indispensable for ensuring a fair transition and guarantee social stability.

ADVANCE HUMAN RIGHTS AND SOCIAL JUSTICE IN THE TRANSITION

How to ensure a just transition?

- Governments must lead the transition of the sector to ensure that all the relevant stakeholders are mobilised and to guarantee that public policies are coherent. Engaging stakeholders and communities in the decision-making and implementation of adaptation policies is essential to meet local knowledge and needs, thus preventing maladaptation.
- Supporting the transition of coastal communities through job retraining and the provision of diverse sources of income and food, is key to safeguarding their livelihoods. Additionally, encouraging transformation in the fishing supply chain, particularly in the food sector, is equally important.
- Supporting and promoting small-scale coastal fisheries is necessary as they provide job opportunities and are central to the socio-economic and cultural fabric of coastal areas.

> **Did you know?**
>
> In Greece, licences to fish Atlantic bluefin tuna are annually allocated to fishers based on social criteria, such as residence on a small island, having minors or disabled children, or employing a crew of fewer than four people.

2 ADAPTING THE AQUACULTURE SECTOR

INCLUDE AQUACULTURE SITES INTO LOCAL SPATIAL PLANNING

Why and how to plan the location of aquaculture sites?
The location of aquaculture sites is a decisive factor in improving the productivity of fish farms, reducing their impact on ecosystems, and avoiding conflicts over ocean and coastal uses. Spatial planning of aquaculture sites should consider local social, economic and environmental issues, informed by the inputs of local stakeholders and populations. Geographic Information Systems (GIS) can provide valuable data to inform decision-making, while inclusive tools such as collaborative mapping can be mobilised to engage stakeholders in this process.

SELECT AND DIVERSIFY FARMED SPECIES

What criteria for selecting species?
Species have traditionally been selected according to growth potential and disease resistance. This selection could incorporate other criteria such as the resilience of species to climate change impacts, and aim to alleviate pressures on wild species. Developing alternative farming such as seaweed and molluscs or species at lower trophic levels, such as plant-eating fish, could align with this objective.

Why and how to diversify farmed species?
Transitioning from monocultures to more diverse farming systems could enhance their long-term productivity and viability. Co-culture models where aquaculture and agriculture are combined (e.g., rice fields and fish farming), and integrated multi-trophic aquaculture (IMTA) can reduce the reliance on wild-caught fish products and curb greenhouse gases emissions, pollution and disease risks. Meanwhile, these systems can create new opportunities, thus promoting social and economic stability within the sector.

DEVELOP *INTEGRATED MULTI-TROPHIC AQUACULTURE*

What is integrated multi-trophic aquaculture?
This approach involves farming multiple aquatic species from different trophic levels together. For instance, one being the species to be fed (for example, fish or shrimps) and the other being the species that feeds off the organic and inorganic waste of the fed species (such as molluscs, seaweed, sea cucumbers, or sea urchins). These "marine permaculture" models aim to improve the efficiency of fish farms by reducing their dependence on wild-caught resources, by minimising wastes and pollution, all the while enhancing ecosystem services.

> **Did you know?**
>
> In Sanggou Bay, China, oyster and abalone farms are co-cultured with kelp and sea cucumbers. China is also experimenting with systems that link onshore aquaculture to marine aquaculture, routing wastewater from intensive inland fish farms to shrimp ponds, and then into multi-trophic ponds of fish, molluscs and algae.

STRENGTHEN SITE BIOSECURITY TO CONTROL DISEASES AND POLLUTION

Enhancing the biosecurity of aquaculture sites aims to reduce the risks to human and animal health by anticipating, controlling and containing disease and pathogen outbreaks. The FAO encourages the development of progressive management pathways for improving aquaculture biosecurity (PMP/AB).

INVEST IN INNOVATIONS FOR ADAPTIVE AQUACULTURE

What innovations can strengthen the adaptability of aquaculture sites?

Local continuous monitoring systems and early warning systems are key to provide information on climate and weather variations, thus guiding fish farmers in their operations and protecting infrastructures. To be operational and effective, data must be accessible and affordable, downscaled, accurate, and timely. In that regard, involving farmers is essential in the development of these tools to meet local needs and capacities.

Did you know?

In Chile, as part of the ARClim project, climate risk maps have been developed to provide information for fish farm managers. They are used in particular to warn fish farms of harmful algal blooms which can cause high mortality among salmon.

Conclusion

Marine fisheries and aquaculture face multiple and unique sustainability challenges, now exacerbated by the compounding impacts of climate change. Ultimately, it is human societies, particularly coastal communities and those reliant on these industries, that are most at risk.

To reverse the spiral of decline that is threatening these sectors, immediate and decisive action is needed. Transitioning to a more virtuous model is not only possible, but desirable to restore healthy, productive resources and ecosystems that benefit marine diversity, coastal regions, and society at large. Public authorities and all the stakeholders concerned must come together to promote production methods that are less harmful, more equitable, and resilient.

A myriad of solutions exist and have been presented throughout this report. In particular, improving knowledge, developing an ecosystem-based approach to fisheries and aquaculture management, striving for continuous impact reduction, co-conceiving strategies with diverse stakeholders, and establishing shared governance wherein states must play a pivotal role.

We must rethink production methods, decision-making and management processes, and the roles and competences of all stakeholder involved. The Ocean & Climate Platform is ready to engage in these collective efforts. Time is of the essence.

Glossary

Acidification	Reduction in the pH value of the ocean caused by higher concentrations of CO_2 in the water.
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.
Adaptation pathways	Dynamic adaptation pathways set out alternative adaptation actions over the short, medium and long-term. As environmental conditions change and socio-economic thresholds are reached, adaptation strategies are able to shift in order to comply with long-term goals.
Biological carbon pump	Refers to the capture of carbon in the ocean through a biological process associated with photosynthesis. Phytoplankton capture atmospheric CO_2 in the surface layer of the ocean through photosynthesis to produce organic matter. 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.
Biosecurity	A set of measures aimed at preventing risks from agriculture, aquaculture, and fisheries on human, animal, and plant health. It includes controlling infectious diseases, invasive species, and genetically modified organisms.
Bottom trawling	A conical net towed by a boat that scrapes the ocean floor to capture the species living there.
Bycatch	Refer to the unintentional capture of non-target marine species.
Climate services	A range of services providing information on current and predicted climate conditions to facilitate decision-making.
Early warning systems	Set of technical and institutional capacities to forecast, predict, and communicate timely and meaningful warning information. Early warning systems are utilised to prepare, act promptly and appropriately to avoid or reduce harm or loss from a hazard on societies and ecosystems.
Ecosystem-based approach to fisheries management	Management method for fisheries that incorporates the functioning of marine ecosystems to promote the conservation and sustainable use of natural resources. The main objectives are to preserve biodiversity, the structure and functioning of ecosystems to maintain ecosystem services.

Eutrophication	Refers to the excessive enrichment of water with nutrients such as nitrogen and phosphorus, often attributed to human activities. This can lead to plankton blooms and decreased oxygen levels in the water, causing imbalances in marine ecosystems.
Ghost fishing	Fishing gear lost or abandoned at sea, which, although no longer in use, continues to capture marine animals and cause damage to natural habitats.
Illegal, Unreported, and Unregulated (IUU) Fishing	Includes fishing activities conducted in violation of national, regional, and international laws and conventions (illegal); catches that are not reported or misreported (unreported); and fishing operations occurring in areas or targeting species that are not managed by any state or regional fisheries management organisation, or that do not comply with conservation and management standards, including in protected areas (unregulated).
Integrated multi-trophic aquaculture	The practice of farming two or more aquatic species of different trophic levels, on the one hand fed species (e.g., fish, shrimp) and on the other, those consuming the inorganic and organic waste of the first species (e.g., mollusks, algae, sea cucumbers, sea urchins). These systems aim to improve farm efficiency, reduce dependence on captured resources, minimise waste and pollution, and enhance ecosystem services.
Invasive alien species	Alien species are animals, plants and all living species whose presence in a region is attributable to human activities (e.g. shipping, aquaculture). Alien species become invasive (IAS) when they establish and spread with negative impacts on nature and human populations. IAS are one of the 5 major drivers of biodiversity loss.
Krill	A small crustacean found in the cold waters of the Antarctic and Arctic. It feeds on phytoplankton and plays a crucial role in trophic networks. It is increasingly harvested for the production of fishmeal used in aquaculture.
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 of ecosystems.
Maladaptation	Actions aimed at tackling climate change, although often unintentionally, can sometimes lead to negative outcomes such as increased greenhouse gas emissions, heightened vulnerabilities of ecosystems and social groups (e.g., higher inequalities, diminished welfare).
Marine finfish farming/ aquaculture	Farming of captive aquatic animals intended for harvest, fed exclusively with fish-based feed, including fishmeal.
Marine heatwaves	Marine heatwaves are unusual periods during which the sea surface heats up for several days to several months, over areas of up to thousands of square kilometres.
Mitigation	Human intervention to curb emissions or enhance carbon sequestration.
Nature-based Solutions	A set of actions aimed at protecting, restoring, and sustainably managing marine ecosystems 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.
Phytoplanktonic bloom	Rapid and sudden increase in plankton populations within an aquatic environment. This natural phenomenon can be amplified by the discharges from human activities, such as agricultural runoff. The proliferation of certain plankton species can be toxic to ecosystems and human health.
Primary production	All the organic matter in an ecosystem produced by plants and microbes through photosynthesis, using light and CO2 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.
Small-scale fisheries	Small-scale fisheries are typically characterised by low capital investment relative to a high labour force, which is often family- or community-based. They usually rely on small-sized vessels or sometimes do not require any, thereby operating close to shore. The catches are relatively small and are mainly consumed directly or sold locally.
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 Goals	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.
Trophic networks	The set of feeding relationships forming a network among different species in an ecosystem, through which matter and energy flow. In the marine environment, the trophic network includes predation interactions, for example, from bacteria to plankton, to fish, and up to marine mammals. Humans consume aquatic resources at every trophic level of this network.
Upwelling systems	Regions of the ocean where cold, nutrient-rich waters well up from the deep ocean to the surface due to favourable winds.
Vulnerability	The propensity to be adversely affected, to cope and adapt to climatic risks considering various variables.

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