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Climate Change: Implications for Fisheries & Aquaculture

Key Findings from the Intergovernmental Panel on Climate Change Fifth Assessment Report

UNIVERSITY OF CAMBRIDGE
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Sustainable Fisheries
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The **Physical Science** of Climate Change

Rising temperatures:

The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) concludes that climate change is unequivocal, and that human activities, particularly emissions of carbon dioxide, are very likely to be the dominant cause. Changes are observed in all geographical regions: the atmosphere and oceans are warming, the extent and volume of snow and ice are diminishing, sea levels are rising and weather patterns are changing.

Projections:

Computer models of the climate used by the IPCC indicate that changes will continue under a range of possible greenhouse gas emission scenarios over the 21st century. If emissions continue to rise at the current rate, impacts by the end of this century are projected to include a global average temperature 2.6–4.8 degrees Celsius (°C) higher than present, and sea levels 0.45–0.82 metres higher than present.

To prevent the most severe impacts of climate change, parties to the UN Framework Convention on Climate Change (UNFCCC) agreed a target of keeping the rise in average global temperature since pre-industrial times below 2°C, and to consider lowering the target to 1.5°C in the near future.

The first instalment of AR5 in 2013 (Working Group I on the physical science basis of climate change) concluded that by 2011, we had already emitted about two-thirds of the maximum cumulative amount of carbon dioxide that we can emit if we are to have a better than two-thirds chance of meeting the 2°C target.

Impact of past emissions:

Even if emissions are stopped immediately, temperatures will remain elevated for centuries due to the effect of greenhouse gases from past human emissions already present in the atmosphere. Limiting temperature rise will require substantial and sustained reductions of greenhouse gas emissions.

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About this Document

The Fifth Assessment Report from the Intergovernmental Panel on Climate Change is the most comprehensive and relevant analysis of our changing climate. It provides the scientific fact base that will be used around the world to formulate climate policies in the coming years.

This document is one of a series synthesizing the most pertinent findings of AR5 for specific economic and business sectors. It was born of the belief that the fisheries & aquaculture sector could make more use of AR5, which is long and highly technical, if it were distilled into an accurate, accessible, timely, relevant and readable summary.

Although the information presented here is a 'translation' of the key content relevant to this sector from AR5, this summary report adheres to the rigorous scientific basis of the original source material.

Grateful thanks are extended to all reviewers from both the science and business communities for their time, effort and invaluable feedback on this document.

The basis for information presented in this overview report can be found in the fully-referenced and peer-reviewed IPCC technical and scientific background reports at: **www.ipcc.ch**

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Key Findings

1. **Climate change and acidification are altering ocean ecosystems in profound ways, with consequent impacts on fisheries and aquaculture.** Drivers include rising water temperature, rising levels of carbon dioxide (CO_2) uptake from the atmosphere and hypoxia (inadequate oxygen).

2. **Projected impacts on fisheries and aquaculture are negative on a global scale;** severely so in many regions. Major impacts include displacement of stocks and, for aquaculture, mortality of shellfish from acidic water. However, in some regions, fish stocks are projected to increase.

3. **Impacts of climate change and ocean acidification are generally exacerbated by other factors such as overfishing, habitat loss and pollution.** This is contributing to an increase in the number of 'dead zones' in the ocean, as well as to an increase in harmful algal blooms.

4. **Coral reef ecosystems are declining rapidly, with the risk of potential collapse of some coastal fisheries.** Incidences of coral bleaching are likely to increase. Aquaculture may be affected through reduced catches of feed-fish and increasing severity of tropical storms and flooding.

5. **Fishers can adapt to some climate impacts.** Measures available include reducing non-climate stressors such as pollution; changing fishing pressure, gear or target species; increasing aquaculture; and moving to dynamic management policies. However, the scope for adaptation to some factors (such as ocean acidification) is very limited. Political conflicts over fishing may increase as stocks migrate.

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The oceans are vital for production of food from fisheries and aquaculture, but their ability to provide this service is sensitive to climate change and ocean acidification. Worldwide, fisheries provide three billion people with around 20% of their average intake of animal protein, and 400 million depend critically on fish for their food. Demand is likely to increase as the global population rises and becomes more affluent.

Climate change affects the physical and chemical properties of the ocean, and these drivers in turn affect the biological properties of marine organisms. In particular, fish and shellfish are affected directly by changes in temperature and oxygen levels, which impact on migration, spawning and feeding patterns, distribution and abundance. Indirectly, fish and shellfish are affected by changes in primary production caused by the direct effects of climate drivers on phytoplankton.

The increasingly acidic ocean is affecting the growth of corals and putting the survival of reefs at risk. It is also resulting in a range of impacts on fish, and shell thinning in molluscs. Aquaculture may be affected by an inability to catch sufficient quantities of feed-fish to meet production needs, through upwelling of acidic water affecting shellfish growth, and through increased flood risk to fish and shrimp ponds in tropical regions. A large number of coastal species are at increased risk of extinction in the coming decades due to climate change, especially where it coincides with pressures such as habitat modification, over-exploitation and pollution.

Current estimates of the total loss of landings to global fisheries by 2050 due to climate change range between USD 17 and 41 billion, based on a global 2°C warming scenario. Losses are likely to be highest in East Asia and the Pacific. Acidification is projected to drive a decline in global shellfish production between 2020 and 2060.

Adaptation is possible in some cases, but very difficult in others. The estimated total cost of adaptation for fisheries globally from 2010 to 2050 is up to USD 30 billion per year.

As a dynamic system, the oceans will continue to respond to past and current changes in global climate. Ocean-wide changes in ecosystems are already occurring and are projected to accelerate from 2050 onwards. Such changes have implications for fisheries management, sustainability, food security, and income generation, particularly in low latitude and small island nations. These changes to ocean systems will continue for centuries.

Executive Summary

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Impacts of Climate Change

Impacts and risks

- **Physical and chemical changes to the ocean** leading to a loss of marine biodiversity
- **Changes in the level of seafood production**, with initial decreases at low latitudes and increases at high latitudes
- **Potential increased levels of IUU fishing** from changes in coastal resources and increasing food insecurity
- **Degradation and loss of tropical and cold water coral reefs**
- **Increased incidences of harmful algal blooms** which threaten ecosystems and fisheries
- **Flood risk to aquaculture** in low lying coastal areas in the tropics
- **Extended breeding periods** experienced for some farmed fish

Physical and chemical changes to the ocean

Rising levels of atmospheric CO_2 result in more CO_2 being taken up by the ocean. This is lowering the pH of the water and causing **ocean acidification**. Bivalve molluscs such as mussels and oysters, along with corals and plankton that form shells from calcium carbonate, are all at risk. Ocean acidification may also have direct effects on fish behaviour and physiology.

Rapid changes in chemical and physical conditions in the oceans have already affected the **distribution and abundance** of marine organisms and ecosystems.

Changes to the distribution of fish populations are affecting the **composition of catches**. In the North Pacific and North Atlantic, range limits of many intertidal species have shifted by up to 50 km per decade. These rates are generally faster than for species on land, and carry the risk that food webs will be seriously disrupted – for example, predators moving away from prey.

400

MILLION PEOPLE DEPEND CRITICALLY ON FISH FOR THEIR FOOD

+2°C

GLOBAL FISHERIES LOSSES ESTIMATED AT USD 17-41 BILLION BY 2050

Concentrations of chlorophyll – an indicator of **net primary production** – in the North Pacific, Indian and North Atlantic Oceans decreased by about 10% in the period 1998–2010. This may be due to man-made climate change or to natural variability. Climate change is projected to cause a further decline of 9% over the 21st century in these open ocean regions.

Rising temperatures reduce the oxygen-carrying capacity of the ocean, which limits the maximum body size that large fish can achieve. As a result, catches of **smaller fish** are predicted for the future. The number of 'dead zones', depleted in oxygen, is increasing, which is affecting coastal ecosystems and fisheries by inhibiting growth. In coastal regions, the primary cause of dead zones is nutrient run-off from land. Likewise, in the North Atlantic, the oceanic Oxygen Minimum Zone (OMZ) is thought to be growing, due to increased stratification (a consequence of warming water). This reduces the volume of water able to support large, predatory fish such as marlin. Further growth of OMZs is projected.

Changes in the level of seafood production

As waters continue to warm, scientists are virtually certain that the **productivity of many fisheries will change**. Spatial shifts of marine species due to projected warming will cause high-latitude invasions and high local extinction rates in the tropics and semi-enclosed seas relative to 2005 levels and based on a global 2°C warming scenario.

Species richness and fisheries catch potential are projected to increase, on average, at mid and high latitudes and decrease at tropical latitudes. Not all fish will be able to adapt, and **some stocks will potentially die out**. Such changes are very likely to increase the vulnerability of people such as artisanal fishers in tropical developing countries, who depend directly on fisheries for food and income, and who are unable to target other stocks or to extend the range of their activity due to financial or technical limitations.

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Coral reef ecosystems are declining rapidly, with the risk of potential collapse of some coastal fisheries.

Migration of fish stocks will also present **issues for governments and fisheries regulators** when attempting to agree fishing opportunities. The movement of Atlantic mackerel to Icelandic waters in recent summers has resulted in Iceland and the Faroe Islands fishing this stock outside of an international management agreement.

Changes in temperature, oxygen levels and food availability in the ocean are likely to alter the **distribution and abundance of top predator species** such as tuna in the Pacific and Indian Oceans, with stocks in both oceans predicted to shift eastwards. Such changes have the potential to affect the economies of many island and developing countries, where small-scale fisheries account for 56% of the catch and 91% of people working in fisheries.

Degradation and loss of tropical and cold water coral reefs

More than half of the world's coral reefs are thought to be at medium or high **risk of degradation** under most climate change scenarios. Reefs support high levels of **biological diversity** and provide an important habitat for fisheries. Areas expected to be worst affected are the Central and Western Equatorial Pacific, parts of Micronesia and Melanesia, and Southeast Asia. Coral reefs support 10–12% of all fish caught in tropical countries, and 20–25% of fish caught by developing island nations. Many of these nations are already considered to be exploiting their **coral reef fisheries** unsustainably, and production of reef fish in the Pacific alone could decrease by up to 20% by 2050.

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Changes in coastal resources and increasing food insecurity may increase illegal, unreported and unregulated (IUU) fishing.

Coastal fisheries and aquaculture

Climate change effects on the abundance of pelagic stocks such as anchoveta, which is used for fishmeal production, could affect **farmed species** such as salmon. For example, lower catches of anchoveta in South America in 2012 resulted in a decline in **fishmeal and fish oil** production, with consequent increases in the price of these commodities.

On the north-western US coast, where upwelling water is naturally more acidic than the average, a decrease in pH has resulted in levels that directly affect **shellfish farming**. In some economically important coastal regions, such as the northern Gulf of Mexico, acidity is projected to increase at twice the global average rate.

Brackish and freshwater aquaculture operations based on pond and lagoon production are particularly at risk in low-lying coastal areas in the tropics. The risks include river basin flooding from increased rainfall, storm surges, and inundation by seawater from rising sea levels.

Fish raised in freshwater aquaculture are at risk from an increased frequency of **disease** exacerbated by stress due to increased temperatures and lower oxygen levels, uncertainties over future water supply, and sea-level rise overcoming coastal defences.

Many phytoplankton species that produce algal toxins generate higher toxin levels under near-future levels of ocean acidification. **Harmful algal blooms** have the potential to cause mass die-offs in farmed fish.

Changes in coastal resources and increasing food insecurity have the potential to increase illegal, unreported and unregulated (**IUU**) fishing.

Positive effects for aquaculture

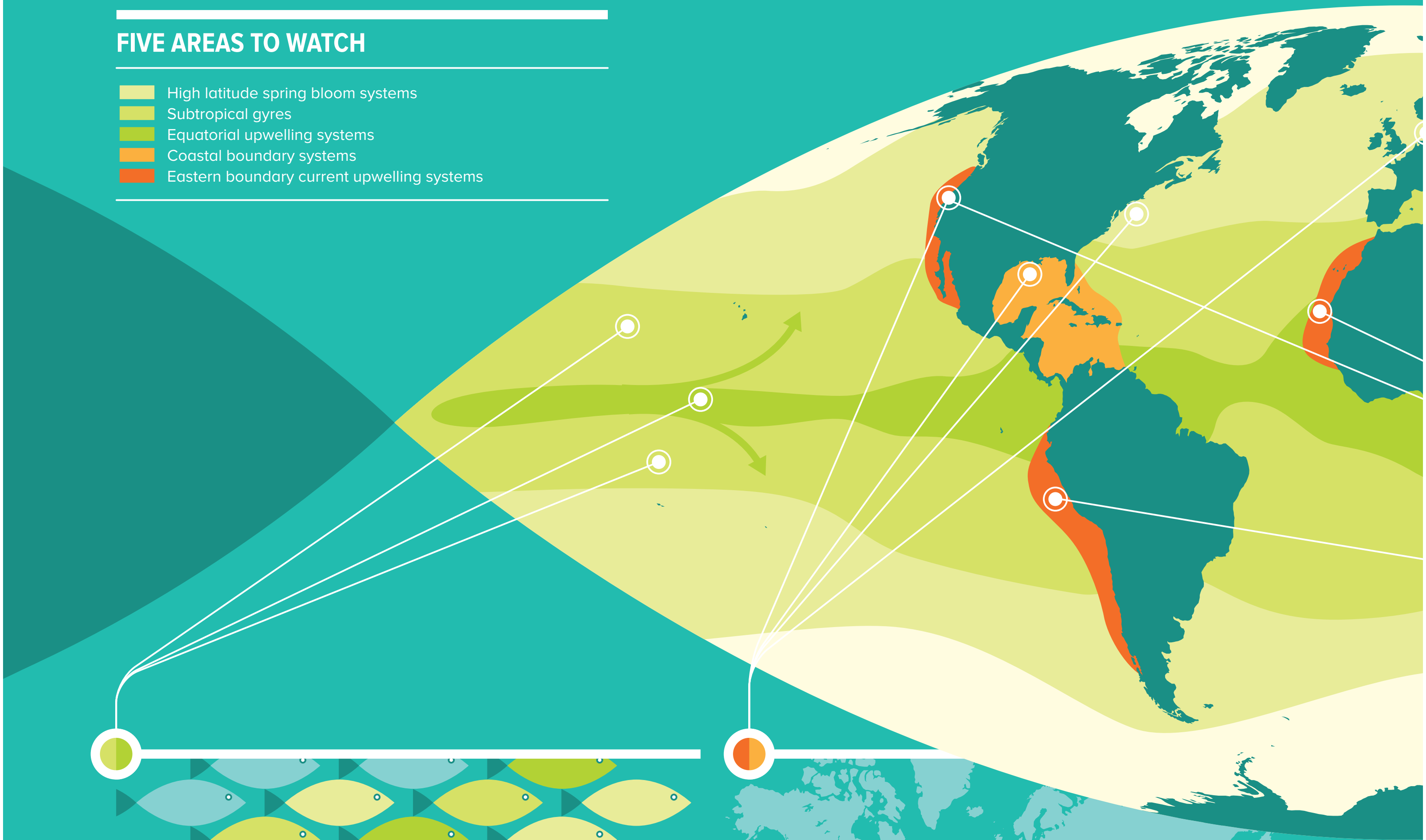
Positive effects of climate change may include faster growth rates and food conversion efficiency, longer growing seasons, range expansion, and new growing areas as a result of decreases in ice cover.

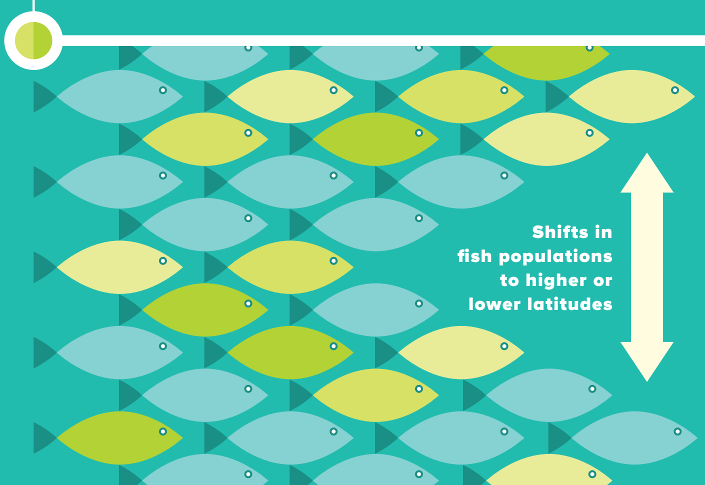
Climate Change Multiplies Existing Threats to the Ocean

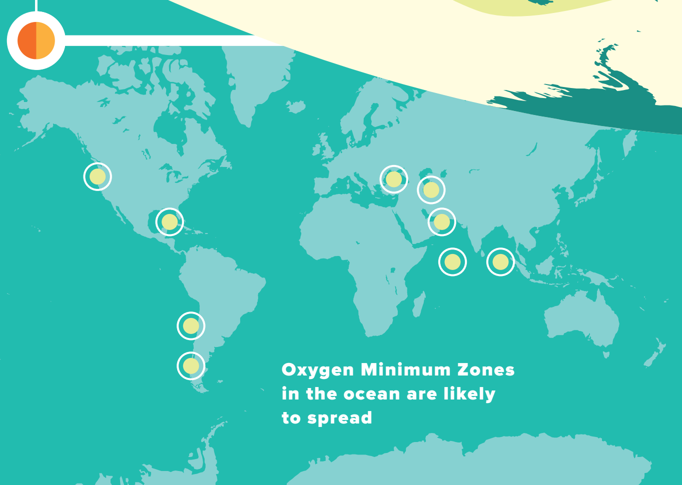
Fisheries provide three billion people with around 20% of their average intake of animal protein, and 400 million depend critically on fish for food. Projected climate change impacts on fisheries and aquaculture are negative on a global scale; severely so in many regions.

FIVE AREAS TO WATCH

- High latitude spring bloom systems
- Subtropical gyres
- Equatorial upwelling systems
- Coastal boundary systems
- Eastern boundary current upwelling systems







The Economics of Fish Redistribution

Fisheries yield is projected to increase by 30–70% in high latitudes, but to fall by 40–60% in the tropics and Antarctica, based on 2°C warming. Large species such as tuna in the Pacific and Indian Oceans are likely to shift eastwards. Global loss of landings is projected at USD17 to 41 billion up to 2050.

OPTIONS Undertake vulnerability assessments. Strengthen coastal zone management. Reduce aquaculture dependence on fishmeal.

Dead Zones are Becoming More Common

The extent of oxygen-depleted ‘dead zones’ in coastal waters is increasing. These are caused by high levels of nutrient run-off from land, exacerbated by higher water temperatures and ocean acidification. In the open ocean, the extent of ‘oxygen minimum zones’ (OMZs), caused by ocean warming, also appears to be increasing. These waters are oxygen-poor in the mid-layers and so are unable to support large active fish.

OPTIONS Reassess and reinforce marine protected areas. Protect mangrove forests, sea grass beds and salt marshes.

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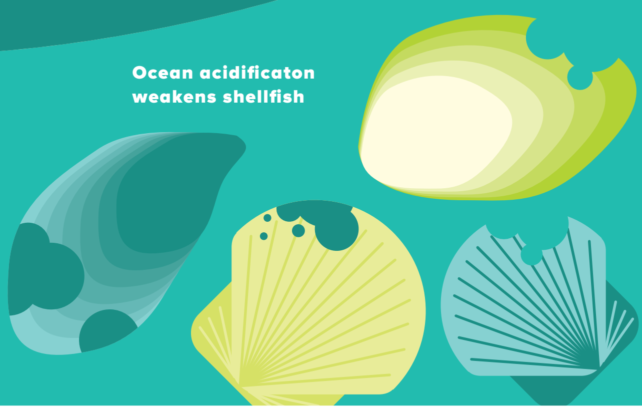
The Ocean's Chemistry is Changing at an Unprecedented Rate

Ocean acidification – the result of enhanced carbon dioxide uptake from the air – puts commercially important fish and shellfish at risk. The ocean's pH has already fallen by 0.1 since pre-industrial times, roughly corresponding to a 30% increase in acidity. If CO_2 emissions continue to rise at the current rate, a further pH drop of 0.3 by 2100 is projected.

Change in ocean surface pH by 2100 under the 'business-as-usual' scenario. -0.6 (MORE ACIDIC) … -0.05



Negative Effects on Shellfish

Shellfish are particularly vulnerable to ocean acidification and other changes in ocean chemistry. Seasonal upwelling of acidic waters onto the continental shelf in the California Current region has been affecting oyster hatcheries along the coast of Washington and Oregon, although the exact role of climate change is unclear. However, if ocean pH continues to fall, overall global production of shellfish fisheries is likely to decrease.

OPTIONS Reduce non-climate change-related stressors. Policies aimed at reducing fossil fuel use across economies will affect the seafood industry.

Coral Reefs at Risk

Coral reef ecosystems are declining rapidly, with the risk of collapse of some coastal fisheries. If CO_2 emissions continue to rise at the current rate, coral reef erosion is likely to outpace reef building during this century. Incidences of coral bleaching as a result of rising temperatures are also likely to increase, with a consequent loss of support and habitat for fisheries and other marine creatures. Coastal protection along with food resources and income from tourism are consequently all at risk.

OPTIONS Create new habitats such as artificial reefs to act as fish nurseries in areas where coral destruction occurs.

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Resilience

A number of measures are available to help fisheries and aquaculture adapt to the effects of climate change. Some are already in existence; for example, shellfish farmers in the north-western US have adapted to changes in the acidity of seawater by blocking the intake when pH levels fall below a certain threshold, or moving their hatcheries to Hawaii. The normal flexibility of fishers in finding new fishing grounds or targeting different species can also be regarded as adaptation. Species of coral algae able to survive in warmer water may naturally displace species that need cooler conditions, thereby slowing reef decline.

The capacity of nature and of the fishing industry to adapt is limited, however, and some adaptation choices are complex. For example, international fisheries management agreements could include flexibility to enable swift responses to changes in fish stock location due to climate change. But such renegotiations would not be straightforward. The same is true for marine protected areas, which may need to be revised in the light of climate-induced ecosystem shifts and changes to habitat.

From a technical perspective, a number of measures already familiar to fishers and fish farmers could be deployed in the context of adaptation to climate change, ocean acidification and hypoxia. For example, selective fishing gear is continually evolving, and could be used to avoid species that are particularly vulnerable; moves to new fishing grounds could be planned on the basis of projected climatic shifts, rather than on the current *ad hoc* basis. Above all, both the seafood industry and governments could decide to accelerate the expansion of aquaculture in order to compensate on a national, regional or global basis for the anticipated fall in wild-caught fish and shellfish.

Adaptation will become progressively more difficult as climate change progresses, and increasingly there are likely to be situations in which it is impossible.

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Domestic and export transport
Improved energy efficiency of vehicles and less carbon-intensive fuels can reduce GHG emissions.

Mitigation Potential

Opportunities for the fishing, aquaculture and seafood industries to reduce greenhouse gas (GHG) emissions are, in general, not specific to the sector. However, policies aimed at reducing GHG emissions across the wider economy could be relevant to this industry among many. (This is in contrast with the transport industry, where many specific mitigation options do exist.)

The seafood industry is generally dependent on fossil fuels for transport, both in fishing vessels and in carrying produce to market. For domestic and export transport, options for reducing GHG emissions include improving energy efficiency of vehicles; switching to less carbon-intensive fuels such as biofuels; fundamentally changing the energy basis (such as a move to electric vehicles); changing the mode of carriage (for example, from air to sea) and reducing the overall number of journeys. Many governments have introduced measures to encourage such options in general, and they will inevitably apply to the transport of seafood. In principle, similar policy measures could be applied to fishing and aquaculture.

For the fishing industry, it is also meaningful to consider ways of mitigating other impacts on the ecosystem, thereby building resilience to climate impacts and ocean acidification. These include some options noted in the previous section. Other options include:

- Undertaking vulnerability assessments of fisheries and aquaculture operations
- Strengthening coastal zone management to reduce land-sourced pollution, over-harvesting and physical damage to resources
- Creating new habitats such as artificial reefs to act as fish nurseries in areas where coral reef destruction occurs
- Reducing aquaculture dependence on fishmeal to help preserve small pelagic stocks.

Protecting some ocean ecosystems will play a direct role in moderating the speed and scale of climate change, as well as building ecosystem health. Mangrove forests, sea grass beds and salt marshes contribute almost 50% of the total organic carbon burial in ocean sediments, known as 'blue carbon'. Protecting these habitats will help constrain the rise in atmospheric CO_2, protect the coast from storm surges, and preserve nursery grounds for fish.

In time, governments may enact policies aimed at quantifying blue carbon, and allow the trading of blue carbon credits on international carbon trading markets. These could fund preservation and restoration projects to slow the progress of climate change.

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Improved policies, management and monitoring systems may help adapt to climate change.

Conclusion

The further and faster that climate change is allowed to progress, the greater the cumulative impacts on fisheries and aquaculture.

Rapid changes in the physical, chemical and biological state of the oceans are having a direct impact on fisheries and aquaculture production, as well as making this sector more vulnerable to non-climate change stressors such as pollution and over-fishing. As a result, there are risks to both current and future production levels, to food security, and to employment in fisheries. There is also potential for increased food insecurity and increased incidences of illegal, unreported and unregulated (IUU) fishing.

Rising sea temperature and ocean acidification are major threats to coral reefs, the degradation of which is highly likely to impact on fisheries production in tropical regions. Ocean acidification is also reducing the ability of marine organisms to produce shells and skeletons, and is interfering with important processes such as navigation in fish. Other risks include an increase in harmful algal blooms, which could affect human health as well as aquaculture and fishing. The recent decline in oxygen concentrations in the ocean, exacerbated by pollution from land-based sources, presents a risk to ecosystems and fisheries.

A certain level of impacts is inevitable, due to the effect of GHGs already in the atmosphere. However, the further and faster that climate change is allowed to progress, the greater the cumulative impacts will be on the fisheries and aquaculture industries.

Adaptation to some climate impacts may be possible in the short term, through improved policies and management and better monitoring systems. Reducing non-climate change-related stressors may help to reduce impacts. Relocating fishing effort and modifying or relocating aquaculture production may offer some opportunity to adapt to changes.

Mitigation options are limited, but policies aimed at reducing fossil fuel use across economies would affect the seafood industry. Measures that promote preservation of mangroves, seagrass meadows and salt marshes will help maintain the ocean's sequestering of CO_2 as well as building resilience to climate change impacts.

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Glossary

ADAPTATION

The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.

AQUACULTURE

The cultivation of marine organisms under controlled conditions, particularly for food.

BIOFUEL

A fuel generally in liquid form, produced from organic matter or combustible oils produced by living or recently living plants.

BLUE CARBON

The carbon captured by the world's oceans and coastal ecosystems. The carbon is stored in the form of biomass and sediments from mangroves, salt marshes and seagrasses.

CLIMATE CHANGE

Any significant change in climate that persists for an extended period, typically decades or longer.

CLIMATE IMPACT

The effects of climate change on natural and human systems.

CORAL BLEACHING

The paling in colour of coral which occurs when stress factors such as high temperature cause the algae living in the coral tissues to be expelled.

DEAD ZONES

Extremely hypoxic (i.e. low-oxygen) areas in oceans and lakes.

FISHERY

An entity engaged in the capture of fish and other seafood for commercial profit, mostly from wild fisheries. Typically defined in terms of the people involved, species or type of fish, area of water or seabed, method of fishing, class of boats, purpose of the activities or a combination of these features.

GREENHOUSE GAS

A gas in the atmosphere, of natural and human origin, that absorbs and emits thermal infrared radiation. Water vapour, carbon dioxide, nitrous oxide, methane and ozone are the main greenhouse gases in the Earth's atmosphere. Their net impact is to trap heat within the climate system.

HARMFUL ALGAL BLOOM

An algal bloom that causes negative impacts to other organisms via production of natural toxins, mechanical damage, or by other means.

HYPOXIA

A deficiency of oxygen.

MITIGATION

A human intervention to reduce the sources or enhance the sinks of greenhouse gases.

OCEAN ACIDIFICATION

A reduction in the pH of the ocean over an extended period, typically decades or longer, which is caused primarily by uptake of carbon dioxide from the atmosphere.

OXYGEN MINIMUM ZONE

Zones in which oxygen concentrations in the ocean are at their lowest.

PROJECTION

A potential future evolution of a quantity or set of quantities, often computed by a model. Projections involve assumptions that may or may not be realized, and are therefore subject to substantial uncertainty; they are not predictions.

RESILIENCE

The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure.

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"Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions."

IPCC, 2013

"There is a growing threat of climate change and acidification to the marine resources upon which we rely. This report is a timely reminder of the pace of change in the oceans and the need for those of us with direct and indirect stakes in the seafood industry to promote action at every level."

CHRIS BROWN, SENIOR DIRECTOR, SUSTAINABLE BUSINESS, ASDA WALMART

Disclaimer:

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The family of summaries, of which this report is part, is not meant to represent the entirety of the IPCC's Fifth Assessment Report (AR5) and they are not official IPCC documents. The summaries have been peer-reviewed by experts both from the business and science communities. The English version constitutes the official version.

About us:

The University of Cambridge Institute for Sustainability Leadership (CISL) brings together business, government and academia to find solutions to critical sustainability challenges.

Cambridge Judge Business School (CJBS) is in the business of transformation. Many of our academics are leaders in their field, creating new insight and applying the latest thinking to real-world issues.

Sustainable Fisheries Partnership (SFP) is a charity dedicated to protecting seafood supplies and livelihoods while achieving environmentally sustainable fisheries and fish farming. The organisation works with businesses to identify the challenges in seafood sourcing and catalyse practical improvements while also maintaining a global public database of fishery information.

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