Ecosystem impacts and food security

H.O Pörtner

WGII CH. 6, Ocean Systems,
ocean products in TS and SPM, CC-Boxes, SYR

UNFCCC Art. 2:

......prevent dangerous anthropogenic interference....

.........allow ecosystems to adapt naturally...

.........ensure that food production is not threatened...

.........enable economic development to proceed in a sustainable manner: Petra Tschakert
Comparing affected sectors and long-term global goals (LTGG) with respect to:

Key risks of impacts
Avoided impacts

Key climate drivers:
- Temperature
- Precipitation
- Ocean warming, acidification and loss of oxygen
- Extreme events

.....allow ecosystems to adapt naturally...
.....ensure that food production is not threatened...

LTGG | Reasons for concern
--- | ---
0.8 | 
1.5 | 
2 | 
4 | 

Key climate drivers:
- Temperature
- Precipitation
- Ocean warming, acidification and loss of oxygen
- Extreme events
Climate change: observed impacts on all continents and in all oceans, e.g.

- Species displacements (marine, freshwater and terrestrial)
- Increase in crop production constrained
- Forest dieback due to drought and heat
- Some unique systems at moderate risk from climate change (...risk may rise if combined with other pressures)
Vulnerable ecosystems

Warm water coral reefs under combined pressures:

Observations:
Loss of live coral cover due to various drivers

...are reefs on the move?

Verons 2009
Latitudinal shifts occurred during the Last Interglacial (LIG) compared to today (Δ SST < 1°C).

...but today’s reefs will be increasingly constrained by ocean acidification (OA) and other pressures.

Kiessling et al. (PNAS 2012)
(B) Risk for marine species impacted by ocean acidification only, or additionally by warming extremes

Projected pH, temperature for 2081–2100
Observed pH, temperature (temperature in °C relative to 1986–2005)

- pH 7.80, +3.7°C → RCP 8.5
- pH 7.91, +2.2°C → RCP 6.0
- pH 7.97, +1.8°C → RCP 4.5
- pH 8.05, +1.0°C → RCP 2.6
- pH 8.07, 0°C → Recent (1986–2005)
- pH 8.17, −0.6°C → Preindustrial (1850–1900)
(A) Risk for terrestrial and freshwater species impacted by the rate of warming

- **Global average:**
  - Most camivores and split-hoofed mammals can’t keep up
  - Most rodents, primates, and molluscs can’t keep up
  - Most trees and herbs can’t keep up

- **Flat landscapes:**
  - RCP8.5 (2050–2090) → ~4°C
  - RCP6.0 (2050–2090) → ~2°C
  - RCP4.5 (2050–2090) → ~1.5°C

Headed towards by 2100:

- 1.5°C
- 2°C
Food security constrained: ....Fisheries

2051-60: displaced and reduced fish and invertebrate biodiversity

..... 2°C:

Combined human pressures: oceans are warming, acidifying, losing oxygen, affecting presently overexploited stocks.

BACKGROUND:
OVERFISHING caused predatory fish biomass to decline (by ≈ 70%!)

MEPS 512: 155–166, 2014
Food security constrained: increase in crop production reduced
Food security constrained:

>1.5°C: high risk of more severe impacts after 2050

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...includes effects of redistributed precipitation, heat and drought events

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<th>Timeframe</th>
<th>Risk &amp; potential for adaptation</th>
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Crop yields increasingly declining with climate change
Some Arctic summer sea ice may be protected under RCP2.6.
Sea level rise beyond 2100 may challenge natural and human systems: affecting habitat, freshwater resources, human society through flood events.

Paleo-observations

5-9 m: ...during the last interglacial (Eemian, 125,000 ya, at 0.7-2°C above pre-industrial)

>7m: ...last time when the atmosphere had 400 ppm CO₂ (in Pliocene, 3-5 Mya)

RCP6.0, 8.5
RCP4.5
RCP2.6

~1.5°C
...climate change: ...avoided impacts ...projected impacts

- climate change velocity slow enough for most terrestrial and freshwater organisms to follow.
- up to half of coral reefs may remain.
- sea level rise may remain below 1 m.
- some Arctic summer sea ice may remain.
- ocean acidification impacts at moderate levels.

- Capacity to increase food production reduced further with some scope for adaptation.
- some unique systems at high risk.
- more than half of coral reefs may be lost.
- risks of combined ocean acidification and warming become more prominent.
- Climate change velocity becomes too high for some species to move sufficiently fast.
- Long-term sea level rise may exceed 1 m: coastal habitat loss, flooding, seawater inundation.
- Arctic summer sea ice may be lost.
- Some unique systems at very high risk. E.g. coral reefs and sea ice systems marginalized.
- Risks of combined ocean warming and acidification become high.
- Crop production at high risk with some room for adaptation.
most projected ecosystem impacts effective at high risk levels

loss of biodiversity, highly reduced fisheries catch potential

crop production at very high risk.

climate change velocity much too high for terrestrial and freshwater species to move sufficiently fast.

long-term sea level rise by far exceeds 1 m: coastal loss, flooding, seawater inundation.

Arctic summer sea ice lost.

some unique systems marginalized.

risks of combined ocean warming and acidification become very high.
Thank you!
Food security constrained:

>1.5°C: high risk of more severe impacts after 2050

Crop yields increasingly declining with climate change
allow ecosystems to adapt naturally...

...ensure that food production

is not threatened...

climate change impacts observed on all continents and in all oceans

• World-wide species displacements due to climate change, marine, freshwater and terrestrial

• Increase in crop production reduced by climate change

• some systems at risk
climate change: observed impacts on all continents and in all oceans

- World-wide species displacements (marine, freshwater and terrestrial)
- Crop production increase constrained
- Forest dieback due to drought and heat
- Some unique systems at moderate risk from climate change (...risk rises if combined with other pressures)

0.8°C

crop yield reduction  forest dieback
Oceans cover ~70% of the blue planet

- create half the oxygen ($O_2$) we use to breathe and burn fossil fuels.
- provide 20% of the animal protein consumed by 3 billion people.
- are home to diverse species and ecosystems valued in tourism
- offer rich biodiversity and resources for innovative drugs or biomechanics.
- sustain coral reefs and mangroves protecting coastlines from tsunamis and storms.
- sustain shipping of 90% of all goods the world uses.
Large-scale climate-related issues in the global ocean

Oceans play a major role in climate regulation globally:
• absorb >90% of the heat accumulating in the atmosphere → ocean warming, hypoxia
• absorb 25% of man-made CO₂ → ocean acidification
• accumulate excess water from melting ice sheets → sea level rise
• redistribution of nutrients → productivity shifts

Human activities also influence ocean conditions locally:
• overfishing, pollution, eutrophication etc.

...with temperature presently being the predominant driver of ongoing global changes,
effects of ocean acidification and hypoxia reported in some areas
OBSERVATIONS IN ECOSYSTEMS

0.8°C:
World-wide species displacements due to climate change, marine, freshwater and terrestrial

Marine displacements

WGII, SPM.2
Climate change velocity can exceed the capacity of species to move:

on the safe side under RCP 2.6

headed towards by 2100

- >4°C
- ~2.8°C
- ~2.4°C
- ~1.5°C
Climate change velocity can exceed the capacity of species to move headed towards by 2100:

- **RCP8.5 flat areas**: >4°C
- **RCP6.0 flat areas**: ~2.8°C
- **RCP4.5 flat areas**: ~2.4°C
- **RCP2.6 flat areas and global average**: ~1.5°C
Ocean temperatures lag behind the global atmospheric mean

courtesy: T. Froelicher
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<td>Temperature driven stock displacement</td>
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<td>Reduced livelihoods and increased poverty <em>(medium confidence)</em></td>
<td>Human adaptation options involve the <strong>large scale relocation of industrial fishing activities</strong> following the regional decreases (low latitude) versus increases (high latitude) in catch potential and shifts in biodiversity. Artisanal local fisheries are extremely limited in their adaptation options by available financial resources and technical capacities, except for their potential shift to other target species.</td>
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| 6.4.1-2, 30.6.2, 30.6.5, Table 30-3                                      |

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The emerging risk: Ocean acidification

Special vulnerabilities of polar species?

IPCC AR5 WGII Figure 6.10, SPM.6
Projections: Ocean acidification, risks for mollusk and crustacean fisheries and coastal protection by coral reefs

WGII, SPM.6
SYR Figure 2.6

Figure 2.6: Observed vs projected pH changes in the ocean.
Synergism of multiple stressors: sensitivity distribution shifted to lower values of $P_{\text{CO}_2}$, a hypothesis

A. Wittmann, H.O. Pörtner, 2013
### Key risk

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#### Evidence for differential resistance and evolutionary adaptation of some species exists but is likely to be limited at higher CO2 concentrations and temperatures reached; adaptation options include the shift to exploiting **more resilient species** for the protection of habitats with low natural CO2 levels, as well as the reduction of other stresses, mainly pollution and limiting pressures from tourism and fishing. |
Observations and Projections: Deoxygenation

RCP8.5: Overall loss in oxygen also affecting Antarctic oceans

respiratory deoxygenation (e.g. deep water) exacerbates acidification

WGI Figure 6.30
Oceans are losing oxygen

Different tolerances to low oxygen levels explain the shift to tolerant communities (unicells and small animals) below 60 µmol l⁻¹....in cool midwater Oxygen Minimum Zones....combined with CO₂ accumulation

Dependence on body size in animals

WGI, 6-30, WGII, 6-11
D. Storch et al., 2014
### Key risk

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### Adaptation issues and prospects

**Oxygen deficiency constraining fish habitat**

| High mortalities and loss of habitat to larger fauna including commercial species due to hypoxia expansion and effects, particularly in EBUE, some SES and CBS regions (high confidence) | Human adaptation options involve the large scale relocation of fishing activities as a consequence of the hypoxia induced decreases in biodiversity and fisheries catch of pelagic fish and squid. Specific fisheries may benefit (Humboldt squid) Reducing the amount of organic carbon running of coastlines by controlling nutrients and pollution running off agricultural areas can reduce microbial activity and consequently limit the extent of the oxygen drawdown and the formation of coastal dead zones. |

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**6.1.1, 6.3.3, 30.5.3-5**

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(1.5°C)
PROJECTIONS

Spatial changes...and a small decrease in ocean primary production

IPCC AR5 WGII Figure 6.13
Small island risks

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The interaction of **rising global mean sea level** in the 21st century with high-water-level events will threaten low-lying coastal areas *(high confidence)*

[29.4, Table 29-1; WGI AR5 13.5, Table 13.5]

- High ratio of coastal area to land mass will make adaptation a significant financial and resource challenge for islands.
- Adaptation options include maintenance and restoration of coastal landforms and ecosystems, improved management of soils and freshwater resources and appropriate building codes and settlement patterns.

![Risk assessment chart](image)
(C) Risk for coastal human and natural systems impacted by sea level rise

Coastal protection and ecosystem adaptation reach limits at many locations

Adaptation to reduce risk needed at many locations

Coastal risks increased nearly globally

Sea level rise

Meters (relative to 1986-2005)

High CO₂

Scenario groups*

Medium CO₂

Low CO₂

*The few available projections for 2300 likely underestimate Antarctic ice sheet contribution

Level of additional risk due to climate change

Undetectable  Moderate  High  Very high

RCPs

2081–2100

2300
Risks involving the oceans, a global perspective:

.....is there risk reduction by adaptation?

.....very limited for some systems: marginalization of coral reefs and polar fauna

POLAR REGIONS
- Risks for Ecosystems
- Risks for Health and Well-Being
- Unprecedented Challenges, Especially from Rate of Change

EUROPE
- Increased Flood Losses and Impacts

ASIA
- Risks for Low-Lying Coastal Areas
  - Loss of Livelihoods, Settlements, Infrastructure, Ecosystem Services, and Economic Stability

SMALL ISLANDS
- Increased Flood Damage to Infrastructure and Settlements
- Risks for Low-Lying Coastal Areas

AUSTRALASIA
- Increased Flood Damage to Infrastructure and Low-lying Ecosystems
- Significant Change in Composition and Structure of Coral Reef Systems

THE OCEAN
- Reduced Fisheries Catch Potential at Low Latitudes
- Increased Mass Coral Bleaching and Mortality
- Coastal Inundation and Habitat Loss

THE OCEAN

WGII, SYR
Regional key risks and potential for risk reduction

**Polar Regions (Arctic and Antarctic)**
- Risks for ecosystems
  - Glaciers, snow, ice, and/or permafrost
  - Rivers, lakes, floods, and/or drought
  - Coastal erosion and/or sea level effects

- Risks for health and well-being
- Unprecedented challenges, especially from rate of change

**North America**
- Increased damages from wildfires
- Heat-related human mortality
- Increased damages from river and coastal floods

**Europe**
- Increased damages from river and coastal floods
- Increased water restrictions
- Increased damages from extreme heat events and wildfires

**Asia**
- Increased flood damage to infrastructure, livelihoods, and settlements
- Heat-related human mortality
- Increased drought-related water and food shortage

**The Ocean**
- Distributional shift and reduced fisheries catch potential at low latitudes
- Increased mass coral bleaching and mortality
- Coastal inundation and habitat loss

**Central and South America**
- Reduced water availability and increased flooding and landslides
- Reduced food production and quality
- Spread of vector-borne diseases

**Africa**
- Compounded stress on water resources

**Small Islands**
- Loss of livelihoods, settlements, infrastructure, ecosystem services, and economic stability
- Risks for low-lying coastal areas

**Australasia**
- Significant change in composition and structure of coral reef systems
- Increased flood damage to infrastructure and settlements
- Increased risks to coastal infrastructure and low-lying ecosystems

**Representative key risks for each region for**

- Physical Systems
  - Glaciers, snow, ice, and/or permafrost
  - Rivers, lakes, floods, and/or drought
  - Coastal erosion and/or sea level effects

- Biological Systems
  - Terrestrial ecosystems
  - Wildfire
  - Marine ecosystems

- Human & Managed Systems
  - Food production
  - Livelihoods, health, and/or economics

**Risk level**
- Present
- Near term (2030–2040)
- Long term (2080–2100)

- Very low
- Medium
- Very high

- Potential for additional adaptation to reduce risk
Perspectives: Foodweb consequences

**Biogeographic shifts**
Some species experience distribution shifts, abundance losses, or become locally extinct (dashed lines). Loss and invasion of prey organisms and/or predators may lead to changing diversity and foodweb structure and result in trophic cascade effects.

**Changes in body size**
Marine water-breathing ectotherms increase their consumption rate and have a smaller maximum body size during warming. Changes in the body size spectrum and food consumption rate may lead to changes in foodweb structure and dynamics.

**Phenological shift**
Changes in phenology due to climate change may lead to mismatch phenomena between predator and prey, which may reduce abundance of the predator.

![Foodweb diagram](IPCC AR5 WGII Figure 6.12)
Devonian
Carboniferous
Silurian
Permian
Triassic
Jurassic
Cretaceous
Palaeozoic
Cenozoic
Mesozoic

500
400
300
200
100
0

Millions of years ago

CO₂ (ppm)

Ordovician
Silurian
Devonian
Carboniferous
Permian
Triassic
Jurassic
Cretaceous

Palaeozoic
Mesozoic
Cenozoic
Widespread impacts attributed to climate change based on the available scientific literature since the AR4

Confidence in attribution to climate change

- very low
- low
- med
- high
- very high

Indicates confidence range

Observed impacts attributed to climate change for

**Physical systems**
- Glaciers, snow, ice and/or permafrost
- Rivers, lakes, floods and/or drought
- Coastal erosion and/or sea level effects

**Biological systems**
- Terrestrial ecosystems
- Wildfires
- Marine ecosystems

**Human and managed systems**
- Food production
- Livelihoods, health and/or economics

* Impacts identified based on availability of studies across a region

Outlined symbols = Minor contribution of climate change
Filled symbols = Major contribution of climate change
Streamflow changes reflecting changes in freshwater supply to sectors, e.g., crop production

\[\approx 2.6^\circ C\]
### Africa

Reduced crop productivity associated with heat and drought stress, with strong adverse effects on regional, national, and household livelihood and food security, also given increased pest and disease damage and flood impacts on food system infrastructure (high confidence)

- Technological adaptation responses (e.g., stress-tolerant crop varieties, irrigation, enhanced observation systems)
- Enhancing smallholder access to credit and other critical production resources; Diversifying livelihoods
- Strengthening institutions at local, national, and regional levels to support agriculture (including early warning systems) and gender-oriented policy
- Agronomic adaptation responses (e.g., agroforestry, conservation agriculture)

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### Asia

Increased risk of drought-related water and food shortage causing malnutrition (high confidence)

- Disaster preparedness including early-warning systems and local coping strategies
- Adaptive/integrated water resource management
- Water infrastructure and reservoir development
- Diversification of water sources including water re-use
- More efficient use of water (e.g., improved agricultural practices, irrigation management, and resilient agriculture)

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### Central and South America

Decreased food production and food quality (medium confidence)

- Development of new crop varieties more adapted to climate change (temperature and drought)
- Offsetting of human and animal health impacts of reduced food quality
- Offsetting of economic impacts of land-use change
- Strengthening traditional indigenous knowledge systems and practices

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### Key risk

Reductions in mean crop yields because of climate change and increases in yield variability. (high confidence)

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WGII, Tables TS.4, 5
Climate change...causing risks
....which were assessed in AR5
(key risks are those relevant to article 2, UNFCCC
“dangerous anthropogenic interference with the climate system”)

PRINCIPLES

Risk Level

Very Low

Med

Very High

Present
Near Term (2030-2040)
Long Term (2080-2100)

Potential for Additional Adaptation to Reduce Risk
Risk Level with Current Adaptation
Risk Level with High Adaptation

2°C

4°C

0.8

~1.5

2

4

warming
Mitigation to 1.5°C...
...losses beyond 50%!!
....not yet taking ocean acidification effects into account)

Frieler et al., 2013:
"To protect at least 50% of the coral reef cells, **global mean temperature change would have to be limited to 1.2° C (1.1 – 1.4° C)**, especially given the lack of evidence that corals can evolve significantly on decadal timescales and under continually escalating thermal stress."
Key expected vs. avoided impact: e.g. oceans

• present (0.85°C):
  • some redistribution of fish stocks
  • reduced growth and decline of some coral reefs
  • large scale shifts of fish stocks and reduced productivity

• 1.5°C:
  • high latitude species invasions
  • reduced productivity of low latitude fisheries
  • ≤ 50 % of warm water coral reefs maintained
  • some Arctic summer sea ice maintained

• 2°C:
  • largely reduced productivity of low latitude fisheries (20% overall)
  • high latitude species invasions, biodiversity loss
  • Arctic summer sea ice lost
  • <= 50 % of warm water coral reefs maintained

• >2°C:
  • warm water coral reefs marginalized, loss of biodiversity, highly reduced catch potential
  • -
Comparing long-term global goals with:

Key risks of impacts
Avoided impacts

Key climate drivers:
- Temperature
- Precipitation
- Ocean hypoxia and acidification
- Extreme events

...allow ecosystems to adapt naturally...
...ensure that food production is not threatened...