TWAP
TRANSBOUNDARY WATERS ASSESSMENT PROGRAMME

Transboundary Waters: A Global Compendium

The Open Ocean: Selected Indicators

Volume 6 - Annex L: The Open Ocean

UNEP

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Volume 6-Annex L

Transboundary Waters: A Global Compendium

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UNESCO – United Nations Educational, Scientific and Cultural Organization · Intergovernmental Oceanographic Commission

GOOS – Global Ocean Observing System

WCRP – World Climate Research Programme

GACS – Global Alliance of CPR Surveys

PML – Plymouth Marine Laboratory

CERMES

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Center for Marine Assessment and Planning, UCSB

GESAMP – Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection

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Contents (Volume 6, Annex I)

United Nations Educational, Scientific and Cultural Organization
Intergovernmental Oceanographic Commission
Global Ocean Observing System
World Climate Research Programme
Global Alliance of CPR Surveys
PML Plymouth Marine Laboratory
CERMES
UBC
Sea Around Us
Center for Marine Assessment and Planning, UCSB
GESAMP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
Dalhousie University Inspiring Minds


Image by: Stöckli, Nelson, Hasler
Laboratory for Atmospheres
Goddard Space Flight Center
http://rsd.gsfc.nasa.gov/rsd
Hurricane Linda west of Mexico
September 9, 1997 17:45 UTC
Data from: NASA, NOAA, USGS

Preface

The Global Environment Facility (GEF) approved a Full Size Project (FSP), "A Transboundary Waters Assessment Programme: Aquifers, Lake/Reservoir Basins, River Basins, Large Marine Ecosystems, and Open Ocean to catalyze sound environmental management", in December 2012, following the completion of the Medium Size Project (MSP) "Development of the Methodology and Arrangements for the GEF Transboundary Waters Assessment Programme" in 2011. The TWAP FSP started in 2013, focusing on two major objecti es: (1) to carry out the fi st global-scale assessment of transboundary water systems that will assist the GEF and other internationa organization to improve the settin of priorities for funding; and (2) to formalise the partnership with key institution to ensure that transboundary considerations are incorporated in regular assessment programmes to provide continuing insights on the status and trends of transboundary water systems.

The TWAP FSP was implemented by UNEP as Implementing Agency, UNEP's Division of Early Warning and Assessment (DEWA) as Executin Agency, and the following lead agencies for each of the water system categories: the International Hydrological Programme (IHP) of the United Nations Educational, Scientifi and Cultural Organization (UNESCO) for transboundary aquifers including groundwater systems in small island developing states (SIDS); the International Lake Environment Commi ee Foundation (ILEC) for lake and reservoir basins; the UNEP-DHI Partnership – Centre on Water and Environment (UNEP-DHI) for river basins; and the Intergovernmental Oceanographic Commission (IOC) of UNESCO for large marine ecosystems (LMEs) and the open ocean.

The fi e water-category specific assessments cover 199 transboundary aquifers and groundwater systems in 43 small island developing states, 204 transboundary lakes and reservoirs, 286 transboundary river basins; 66 large marine ecosystems; and the open ocean, a total of 756 international water systems. The assessment results are organized into five technical reports and a sixth volume that provides a cross-category analysis of status and trends:

Volume 1 – Transboundary Aquifers and Groundwater Systems of Small Island Developing States: Status and Trends
Volume 2 – Transboundary Lakes and Reservoirs: Status and Trends
Volume 3 – Transboundary River Basins: Status and Trends Volume 4 – Large Marine Ecosystems: Status and Trends
Volume 5 – The Open Ocean: Status and Trends
Volume 6 – Transboundary Water Systems: Crosscutting Status and Trends

A *Summary for Policy Makers* accompanies each volume.

Volume 6 presents a unique and first global overview of the contemporary risks that threaten international water systems in five transboundary water system categories, building on the detailed quantitative indicator-based assessment conducted for each water category. As a supplement to Volume 6, this global compendium of water system information sheets provides baseline relative risks at regional and system scales. The fact sheets are organized into 14 TWAP regions and presented as 12 annexes. Volume 6 and the compendium are published in collaboration among the five independent water-category based TWAP Assessment Teams under the leadership of the Cross-cutting Analysis Working Group, with support from the TWAP Project Coordinating Unit.

Transboundary Waters: A Global Compendium

The technical teams of the Transboundary Waters Assessment Programme(TWAP) assessed transboundary aquifers, lakes & reservoirs, river basins, and large marine ecosystems and prepared information (fact) sheets for water systems that were evaluated. Each fact sheet provides basic geomorphological information and presents baseline values of quantitative indicators that were used to establish relative risk levels. The water system fact sheets are organized into 14 TWAP regions that were used in the Crosscutting Analysis described in Volume 6. The regional compilations are presented as 11 annexes (A-K) of a global compendium, combining Southern & Southeastern Asia into one annex (I), and the Pacific Island Countries, Australia & Antarctica into another (Annex K). Each annex highlights contemporary regional risks as well as water system-specific risks. The annexes are:

Annex A. Transboundary waters of Northern America
Annex B. Transboundary waters of Central America & the Caribbean Annex C.Transboundary waters of Southern America
Annex D. Transboundary waters of Eastern, Northern & Western Europe Annex E.Transboundary waters of Eastern Europe
Annex F. Transboundary waters of Western & Middle Africa Annex G. Transboundary waters of Eastern & Southern Africa
Annex H: Transboundary waters of Northern Africa & Western Asia
Annex I: Transboundary waters of Southern & Southeastern Asia Annex J :Transboundary waters of Eastern & Central Asia
Annex K: Transboundary waters of the Pacific Island Countries, Australia & Antarctica

In the case of the open ocean, which is the largest transboundary water system of planet earth, selected quantitative indicators prepared by the Open Ocean Assessment Team, are compiled in Annex L to highlight the contemporaneous and projected states of the global ocean.

Annex L: The Open Ocean: Selected Indicators

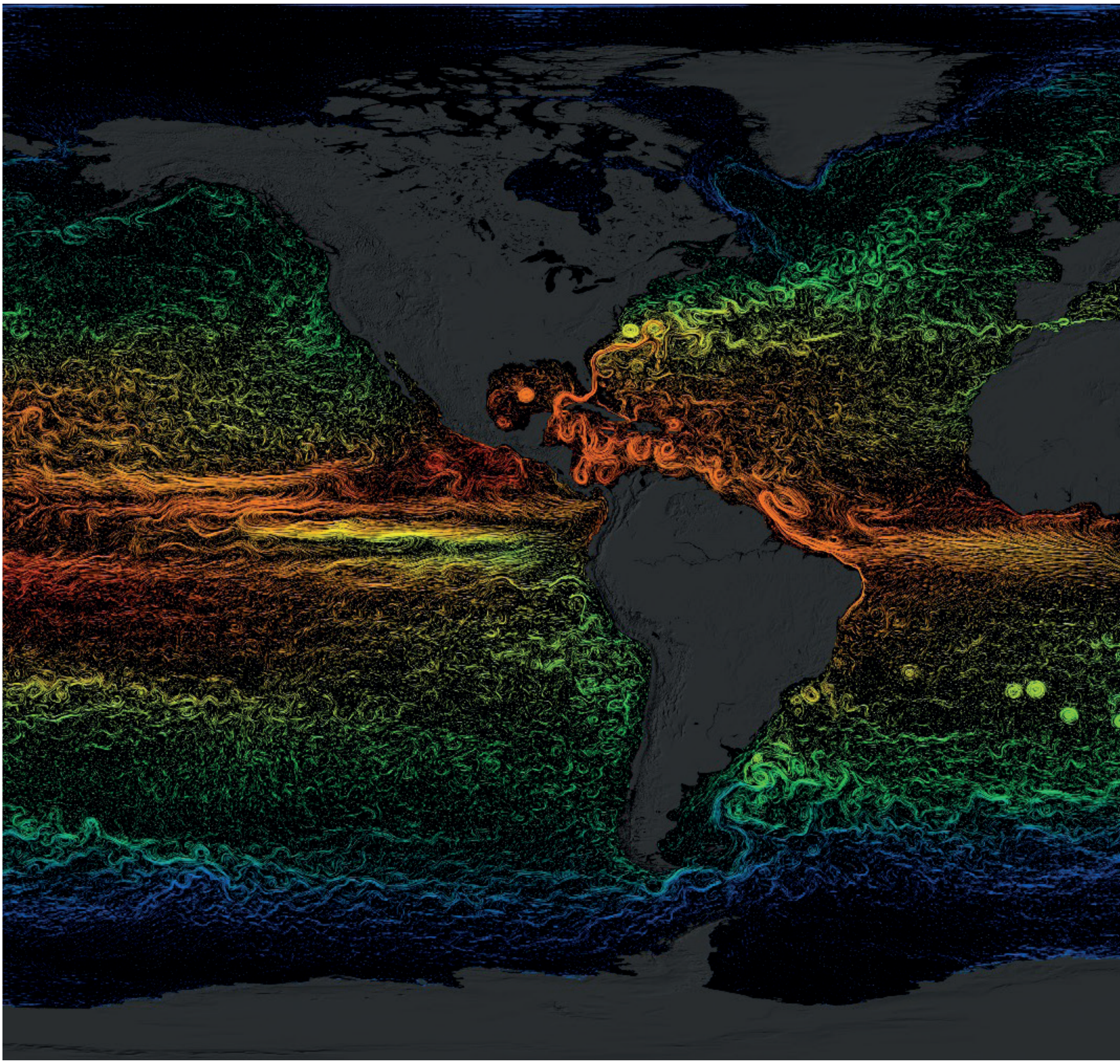
All information sheets and indicator maps for the open ocean may be downloaded individually from the following websites:

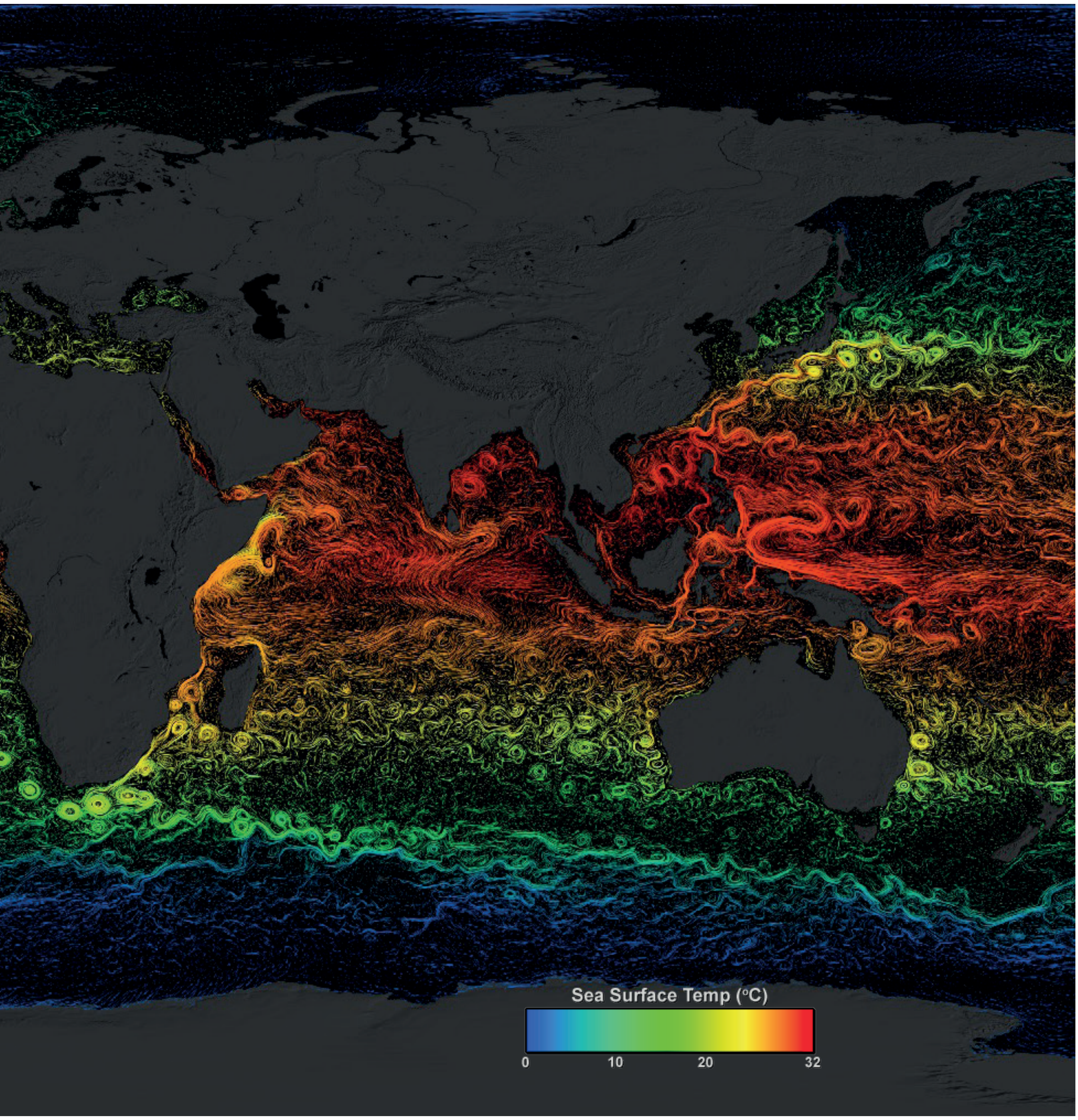
Transboundary Aquifers: http://twapviewer.un-igrac.org
Transboundary Lakes/ Reservoirs: http://ilec.lakes-sys.com/
Transboundary River Basins: http://twap-rivers.org
Large Marine Ecosystems: http://onesharedocean.org
Open Ocean: http://onesharedocean.org

All TWAP publications are available for download at http://www.geftwap.org

Over the long term, it is envisioned that these baseline information sheets will continue to be updated by future assessments at multiple spatial and temporal scales to better track the changing states of transboundary waters that are essential in sustaining human wellbeing and ecosystem health.

This map shows global sea surface current flows in colors of corresponding sea surface temperature data. These current systems, along with the sub-surface circulation, transport and distribute heat and carbon in the oceans. (NASA/ Goddard Space Flight Center Scientific Visualization Studio at http://svs.gsfc.nasa.gov/3821)



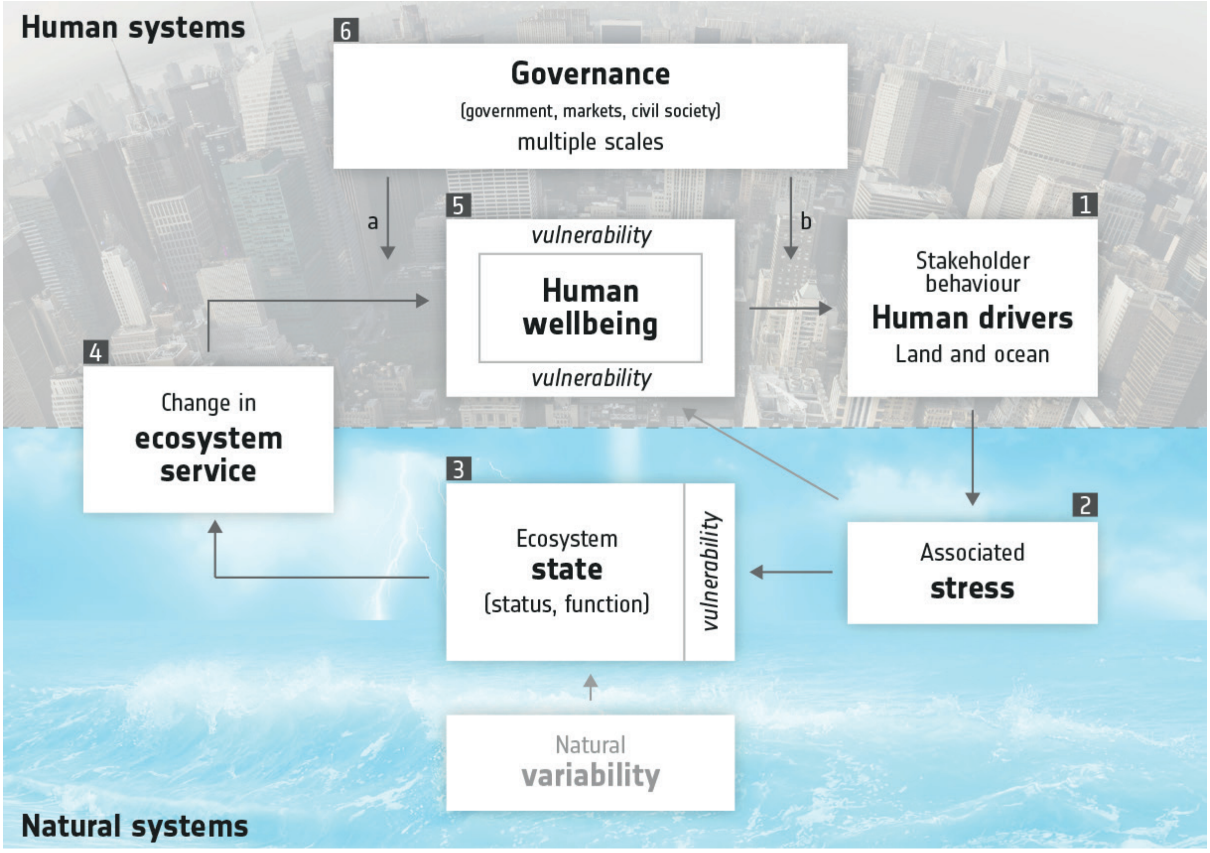

Sea Surface Temp (°C)
0
10
20
32

Introduction

The *Transboundary Water Assessment Programme (TWAP)* was initiated by the Global Environment Facility (GEF) to create the first baseline assessment of all the planet's transboundary water resources. The *Open Ocean Assessment* is one of five assessments of transboundary water systems (see www.geftwap.org).

Conceptual Framework

This conceptual framework maps out the interactions between human and natural systems used in the open ocean assessment of the Transboundary Water Assessment Programme.

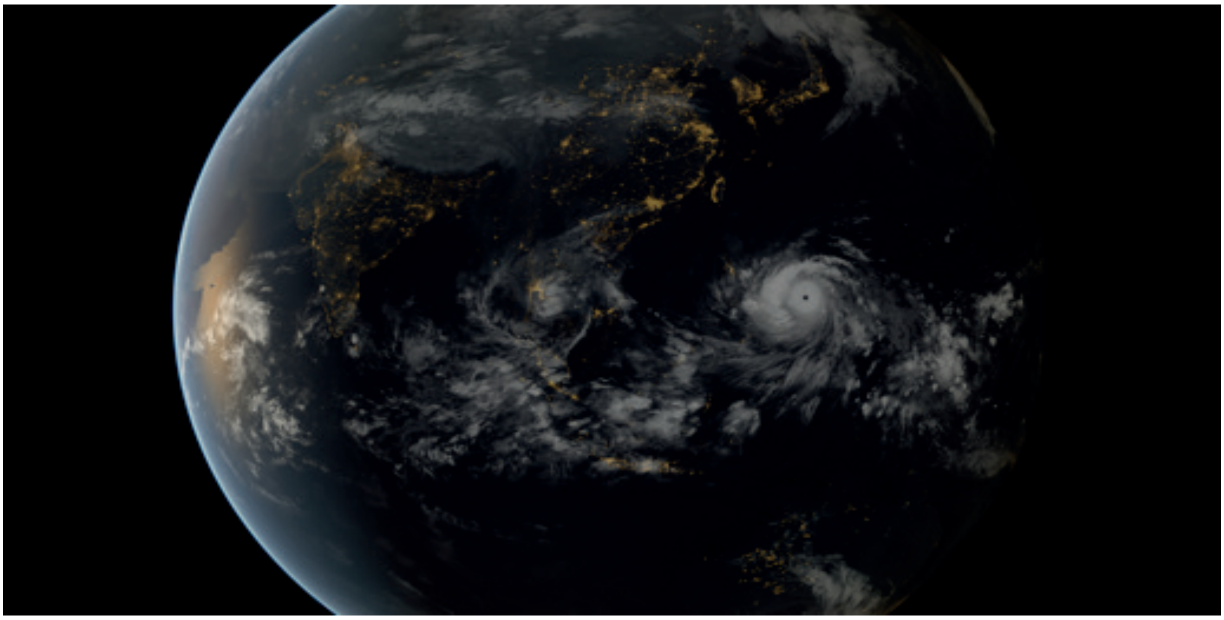


The Open Ocean assessment is aimed at clarifying the relationship between human and natural systems, to help identify particular indicators and their relevance, where assumptions have been made, and where gaps exist in knowledge and data. These interactions between humans and natural ecosystems were captured in a "conceptual framework", based on the idea of "causal chains" (see figure above). The framework was centered on the vulnerability of both natural systems to external pressures and consequences for the sustainable production of ecosystem services, and of humans to ecological changes. In brief, human activities have associated stressors that in turn impact natural systems and this in turn affects the delivery (and value) of services to people (starting in Box 1 and going clockwise). Ultimately, the assessment wanted to know how people are affected (Box 5: Human Wellbeing). However, indicators for all elements of the human and natural systems could not be developed - as the systems and their interrelationships on different time and spatial scales are complex and hard to identify and monitor. So the Open Ocean Assessment developed rapid "early indicator" metrics that are earlier in the causal chain.

Human activities have associated stressors that in turn impact natural systems and this in turn affects the delivery (and value) of services to people. For the human system, all interactions between boxes are strongly mediated by socio-economic factors. Governance is defined broadly as including government, markets, and civil society, operating at global, regional, national, and local scales. It has strong connections to human-wellbeing. As well, effective governance is fundamental to achieving healthy ecosystems (inclusive of people), and in this context, links to sustaining ecosystem services (Box 4) in addition to other politically-negotiated goals.

For the natural system, we concentrate on stresses associated with human activities (Box 2, for ocean side may be from ocean-based activities like fishing and land-based activities like carbon emissions), how they affect the state of the ecosystem under consideration (Box 3, modulated by the ecosystem vulnerability), which may lead to changes in the ecosystem services (Box 4, eg. fish catch). Finally, crossing the natural-human system boundary, the changes can lead to consequences for people, buffered or exacerbated by their vulnerability (surrounding Box 5). Natural variability, whether a regular seasonal change or more complex interaction within the natural system, will need to be evaluated separately from the interaction with the human system, so that the impact of a change in the human system - through a change in governance or a particular GEF intervention, can be separately identified.

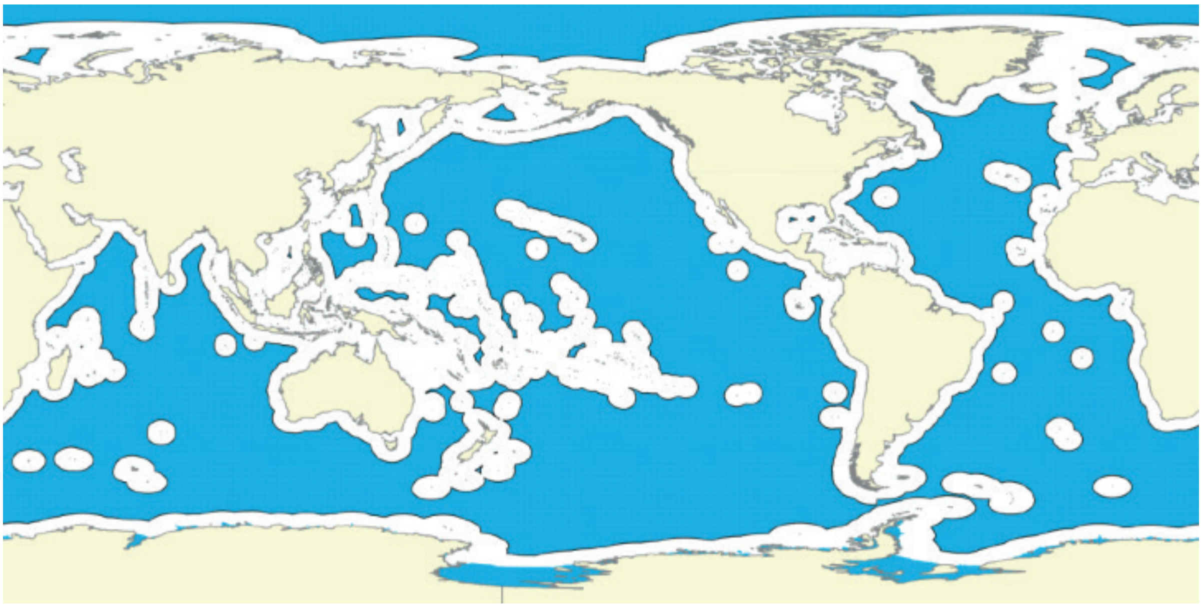
Typhoon Haiyan approaching the Philippines (13:00 UTC, 7 November 2013). Haiyan landed as a Category 5 equivalent super typhoon on the Saffir-Simpson hurricane wind scale, causing 6340 confirmed fatalities and nearly $3 billion (2013 USD) in property damage. (2013 EUMETSAT)



Spatial coverage

The 'open ocean' is the largest areas of global commons, vital to life on the planet, and under the legal jurisdiction of no single nation but the common stewardship of all in 'areas beyond national jurisdiction' (ABNJ). This area is made up of the ocean beyond exclusive economic zones (EEZs). From a scientific perspective, the open ocean includes all areas beyond the shallow continental shelf break. Due to the strong connections between the open ocean and coastal areas, a global ocean perspective is often taken. Where indicators are shared with the Large Marine Ecosystems, this assessment has focused on ABNJ.

Areas Beyond National Jurisdiction (ABNJ) are blue. The white areas depict exclusive economic zones (EEZs) (or 'areas within national jurisdiction').



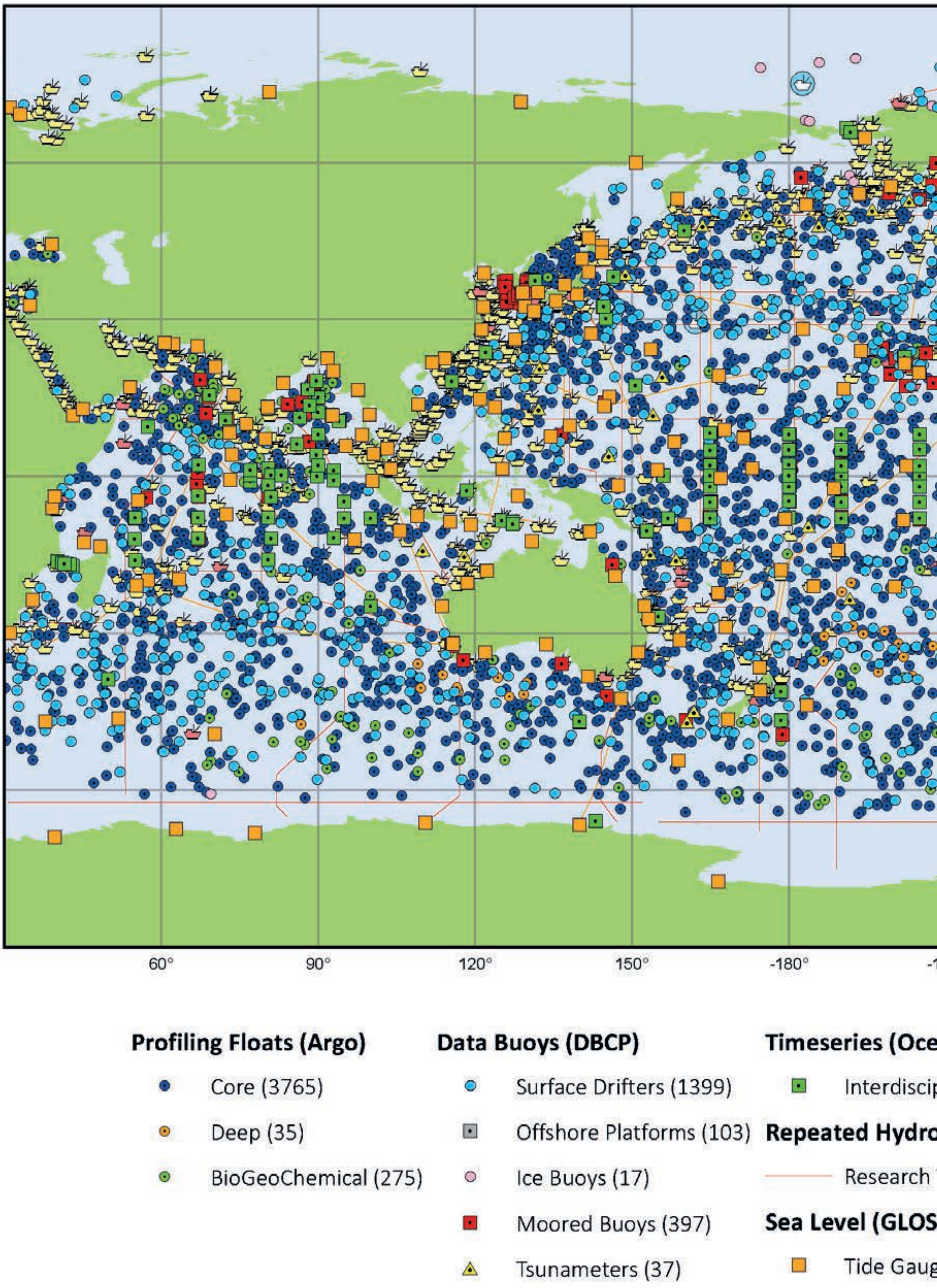
Assessment Indicators for an under-monitored open ocean

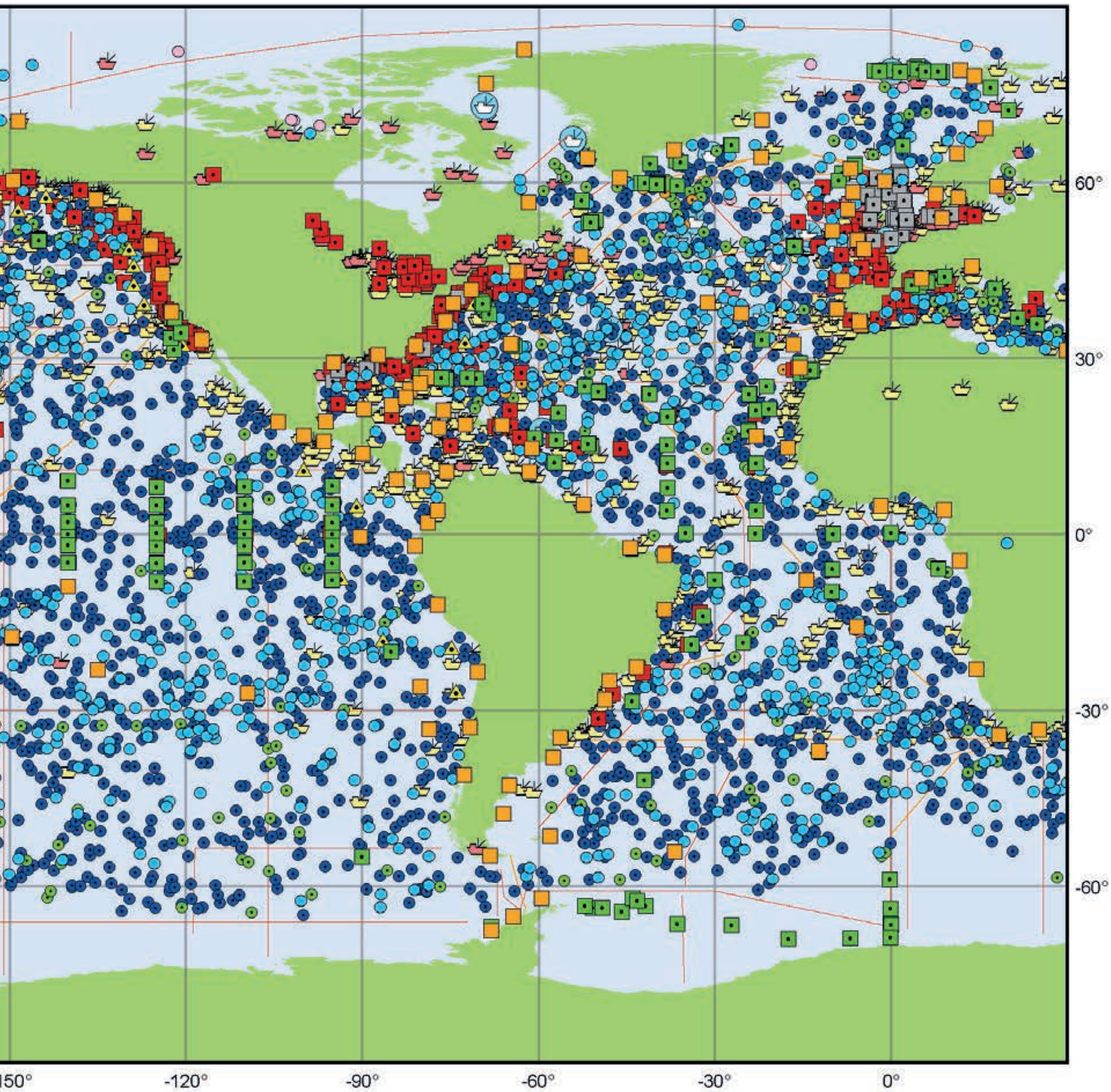
The Open Ocean Assessment is focused on 6 themes broadly aligned with governance arrangements covering areas beyond national jurisdiction, including governance of issues requiring global transboundary solutions. It provides a baseline indication of the state of the open ocean and its ecosystems and services, their connection to human wellbeing including global connections to the coast; and where possible, projected future state at 2030, 2050, and/or 2100. This assessment involved data assembly, index and indicator development, and theme reviews by experts - assessing the indicators where possible and assessing scientific literature where sustained global monitoring does not exist.

The table below identifies the expert assessments, indices and indicators (including projections) used in the assessment. It also identifies the implied sustained monitoring requirement and present-day readiness of monitoring systems such as the natural system-focused Global Ocean Observing System (GOOS) to systematically capture the information needed to update this assessment in the future (based on the readiness scale of the Framework for Ocean Observing ranging from: concept, pilot, to mature). Even for mature portions of observing systems (i.e. the physics of ocean climate), sustained financial and institutional support as well as capacity for and coverage of global observations and information delivery remains patchy and fragile.

THEME	**Expert Assessment**	**INDEX / INDICATOR (Baseline)**	**INDEX / INDICATOR (Projected to 2030, 2050, and/or 2100)**	**Sustained monitoring requirement for assessment** *includes both natural system and human data*	**Readiness of sustained observations** *(concept, pilot, mature, from least to most ready)*
Governance	Existence of Open Ocean Governance Arrangements			Monitoring of governance arrangements covering ABNJ	concept
Climate	Climate and Ocean interactions	Ocean warming	Ocean warming	Physical / biogeochemical ocean variables	mature / pilot
		Deoxygenation	Deoxygenation (to 2090)	Oxygen	pilot
		Aragonite saturation state	Aragonite saturation state	Carbonate system	mature
			Sea Level Rise Risk Index (to 2100)	Sea level, temperature, cryosphere	mature / pilot
				human exposure and vulnerability to sea level	mature
Ecosystems, habitats and biodiversity	Ocean Acidification Risk	Primary productivity		ocean colour in situ validation	mature pilot
		Phytoplankton		phytoplankton	concept
		Zooplankton		zooplankton	pilot
		Coral reefs (tropical ecosystem)	Coral reefs (tropical ecosystem)	coral health	pilot
		Pteropods (polar ecosystem)	Pteropods (polar ecosystem)	zooplankton	pilot
		Biodiversity (based on OBIS records)		Biodiversity (species records)	concept
Fisheries	Sustainability of fisheries	Marine Trophic Index	Fish Catch Potential	fish catch data by taxonomic group and trophic level	mature
		Fishing in Balance Index		fish catch data by taxonomic group and trophic level over time	mature
		Bottom Impacting Gear		method of fish catch	mature
		Demersal Fishing		method of fish catch	mature
		Tuna trends 1950 to 2010		fish catch data	mature
Pollution	Pollution (general)	Plastics		time series of ocean contaminants from strategically selected sites	concept

Main *in situ* elements of the Global Ocean Observing System. (WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorogology in-situ Observing Programmes Support Centre ((JCOMMOPS) at www/jcommops.org)





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A changing ocean climate

The ocean's dominant role in climate of storing and distributing heat and moisture means it will drive changes of rainfall and drought over land. Sea level rise from heat expansion and melting land ice threatens coastal ecosystems and human habitat. Ocean climate changes through temperature, acidification, and deoxygenation have direct impact on ocean ecosystems.

EXPLAINING PROJECTED CLIMATE CHANGE SCENARIOS

The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report 2014 (AR5) provides the most up-to-date comprehensive assessment of scientific information on climate change and the ocean and an overview of impacts already observed or expected from a range of climate change scenarios. The Open Ocean Assessment uses projections of the future state of the open ocean using the scenarios outlined in the **IPCC 5th Assessment Report (2014),** for 2030 and 2050, and when intermediate output was not available, for 2100.

Representative Concentration Pathways (RCP) are tools used by researchers to test the consequences different greenhouse gas emission scenarios, based on global political choices. There is a range of scenarios but this Assessment uses two:

- **RCP8.5 'Business As Usual' (BAU)** – where nothing changes from the current situation, there is continuing growth of greenhouse gas concentrations in the atmosphere.
- **RCP4.5 ' two degree stabilization scenario' or 'Moderate Mitigation' (MM)** – where there is a continued rapid initial growth of greenhouse gas concentrations, but stabilizing concentrations from 2070 onward. Parties to the Paris Agreement of the UNFCCC adopted in December 2015 have agreed to hold "the increase in global average temperature to well below 2 °C above pre-industrial levels"

EXPLAINING 'CERTAINTY' AND 'RISK' TERMS

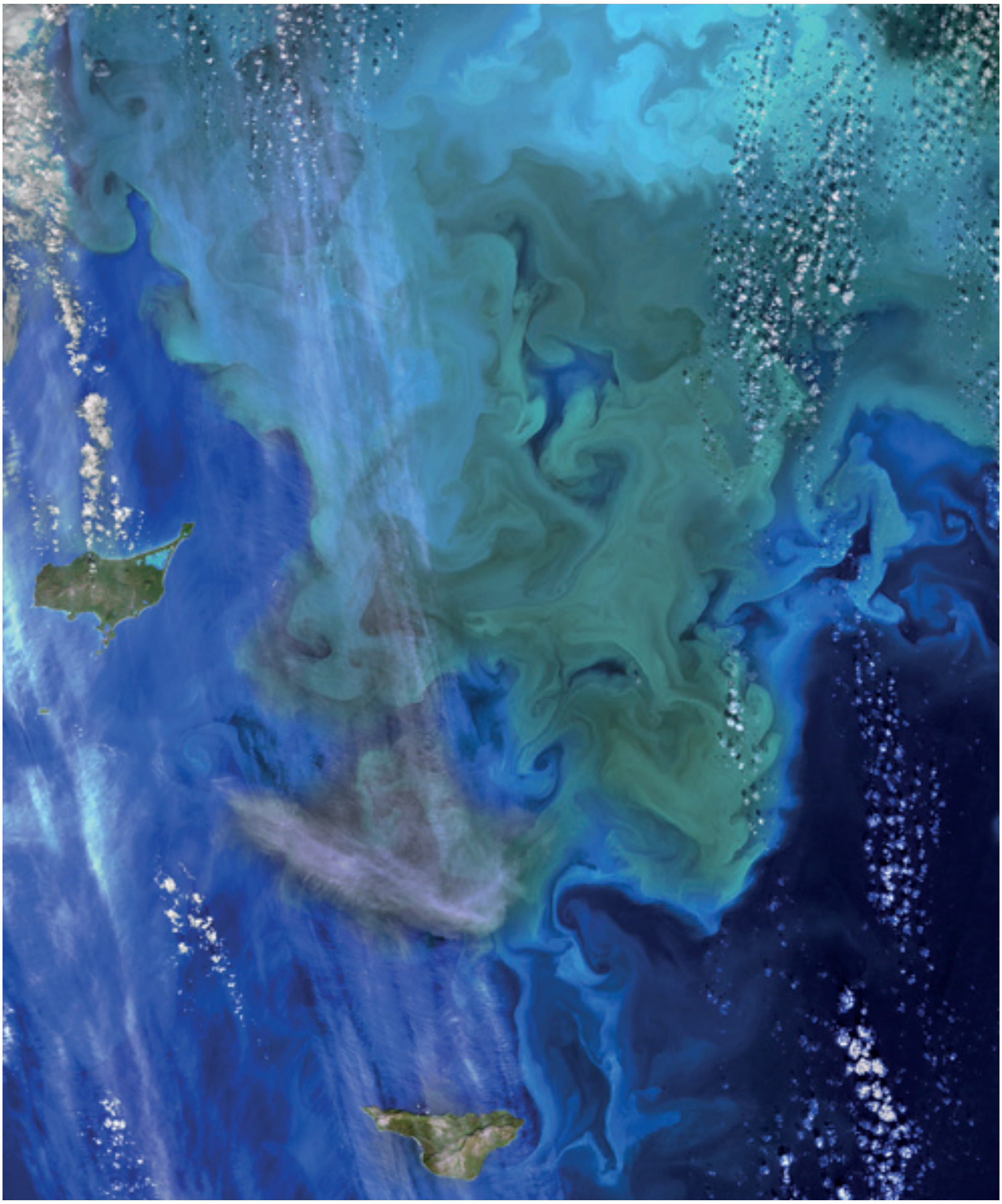
Projections are based on models, which provide a 'trend' for any given situation. Because models show 'trends', language to describe these trends needs to reflect the level of 'certainty' with respect to the outcome of the calculations, based upon the spread in the model outcomes.

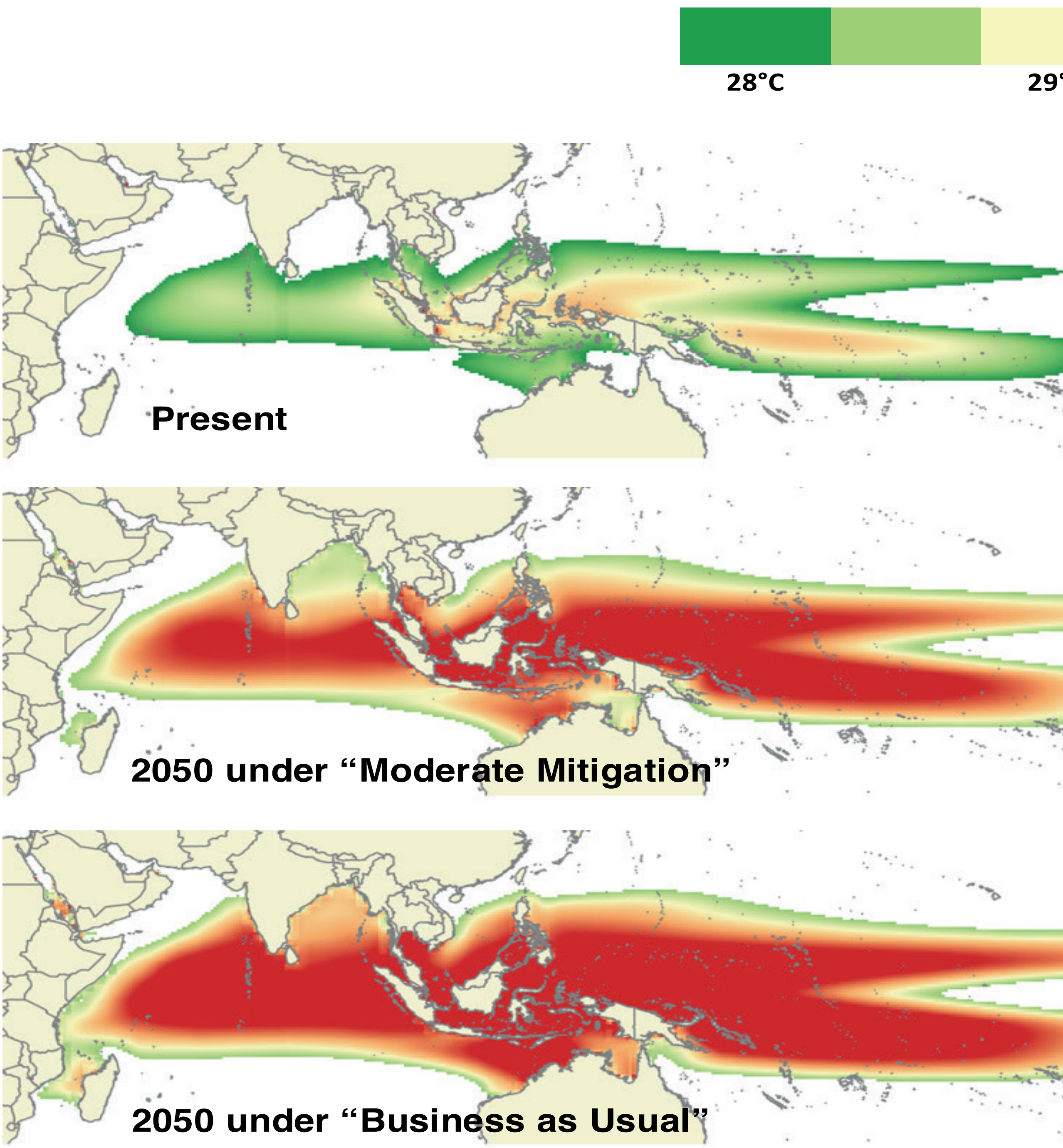
Throughout this assessment, language of 'certainty' is based on the IPCC's 'Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties' (2010) where categories of 'certainty' are considered:

Term*	Likelihood of the Outcome
Virtually certain	99-100% probability
Very likely	90-100% probability
Likely	66-100% probability
About as likely as not	33 to 66% probability
Unlikely	0-33% probability
Very unlikely	0-10% probability
Exceptionally unlikely	0-1% probability

Similarly, when referring to the 'risk' of occurrence or change, language reflecting the approximation of a risk level has also been used consistent with all TWAP water bodies, with the categories: Low, Medium, High, Extreme, Critical

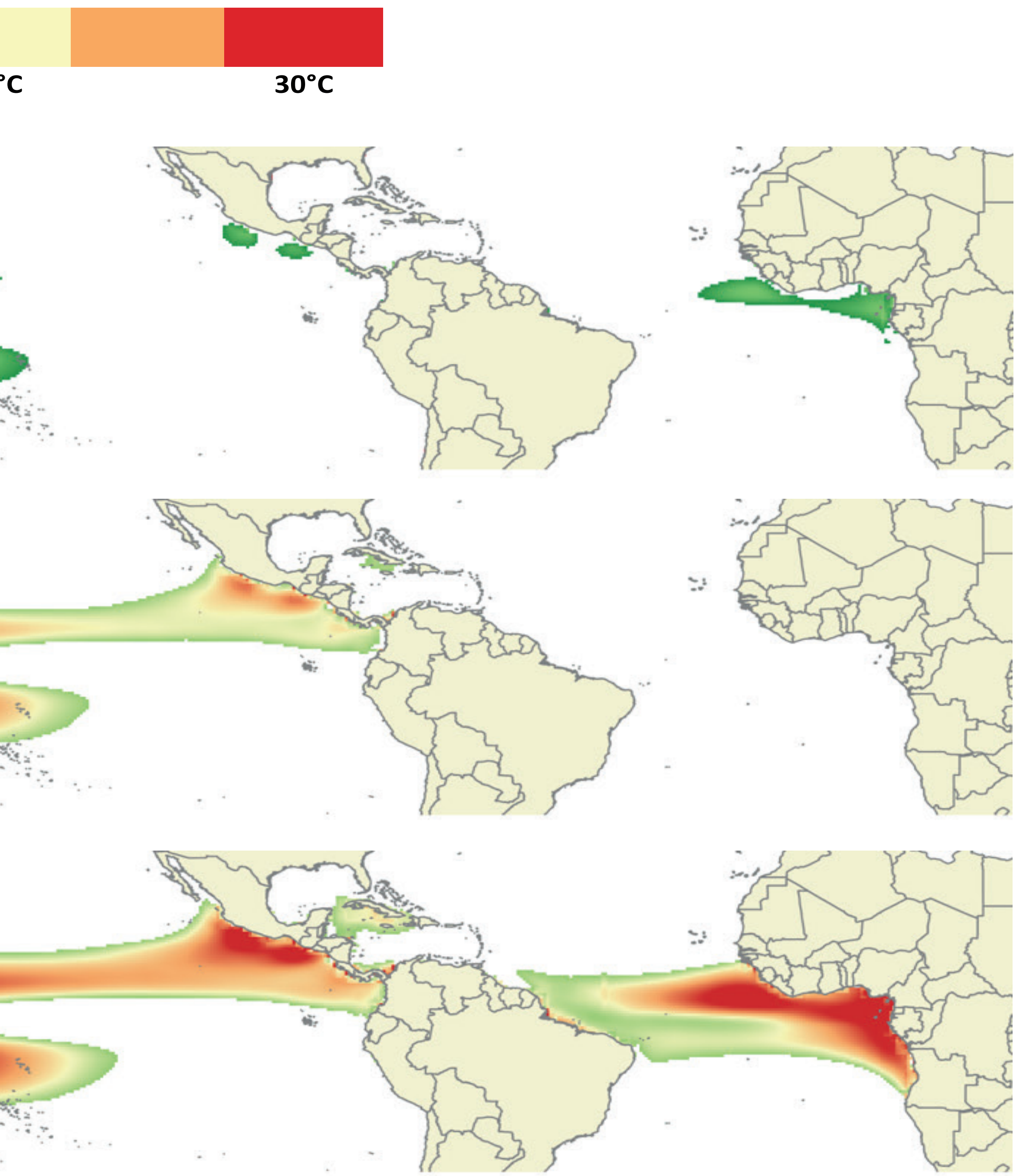
Phytoplankton bloom in the Bering Sea (NASA Earth Observatory Images by Jesse Allen and Norman Kuring, using Landsat 8 data from the U.S. Geological Survey.





A warming ocean

Ocean warming dominates the energy stored in the climate system in the last 40-50 years and accounts for approximately 93% of the excess heat accumulated between 1971 and 2010.



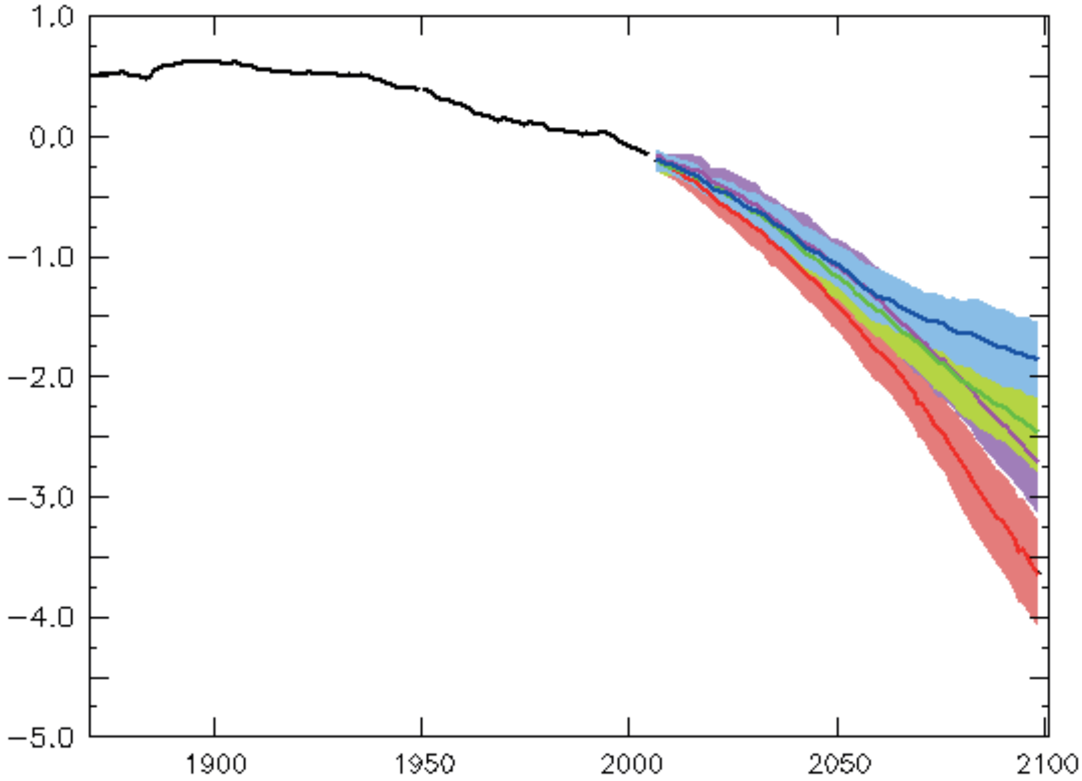
The areas of regions with very warm water (> 28 ºC), known as open ocean Warm Pool shown above, are engines of tropical circulation and rainfall patterns. They will increase substantially by 2050 under both the "Moderate Mitigation" and "Business As Usual" scenarios, with impacts on regional climate and ecosystems.

Decreasing ocean oxygen content

One of the major climate stressors of open ocean ecosystems is deoxygenation. The concentration of dissolved oxygen (O2) is a major determinant of the distribution and abundance of marine species globally. Open ocean deoxygenation has already been recorded in nearly all ocean basins during the second half of the 20th century. Increased temperatures are responsible for approximately 15 % of the observed change, and the remaining 85 % is due to reduced O2 supply from increased ocean stratification and increased deep-sea microbial respiration.

The North Pacific, the North Atlantic, the Southern Ocean, the subtropical South Pacific and South Indian oceans will all undergo deoxygenation by the end of the century (BAU scenario).

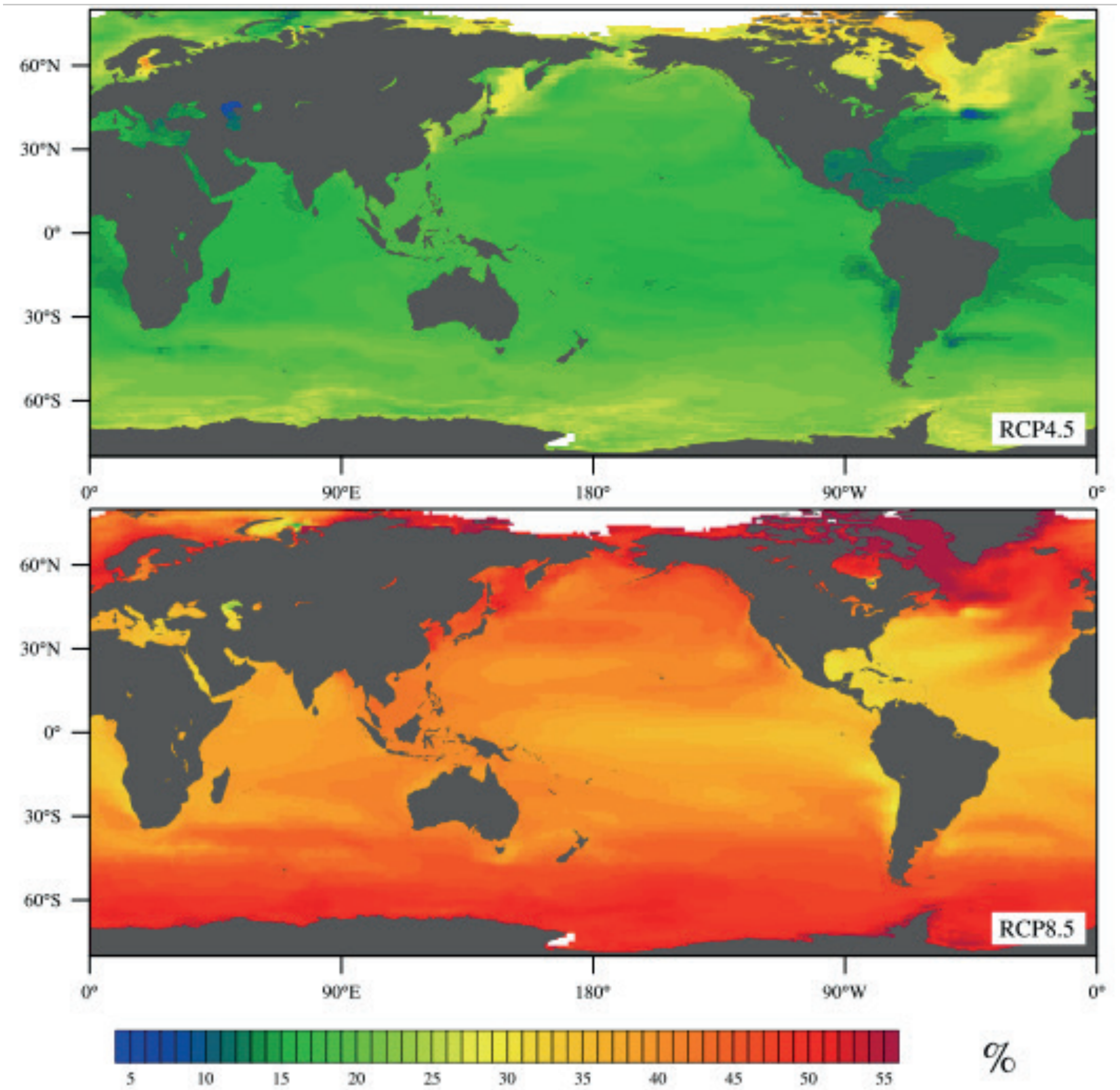
Observed (black line) and projected O_2 concentration change (per cent) relative to mean concentration in the 1990s. The black line shows historical simulations tuned with available observations. Colored lines represent four RCP scenarios: RCP 2.6 – blue, RCP 4.5 'Moderate Mitigation' – green, RCP 6.0 – lavender and RCP 8.5 'Business as Usual' – red.



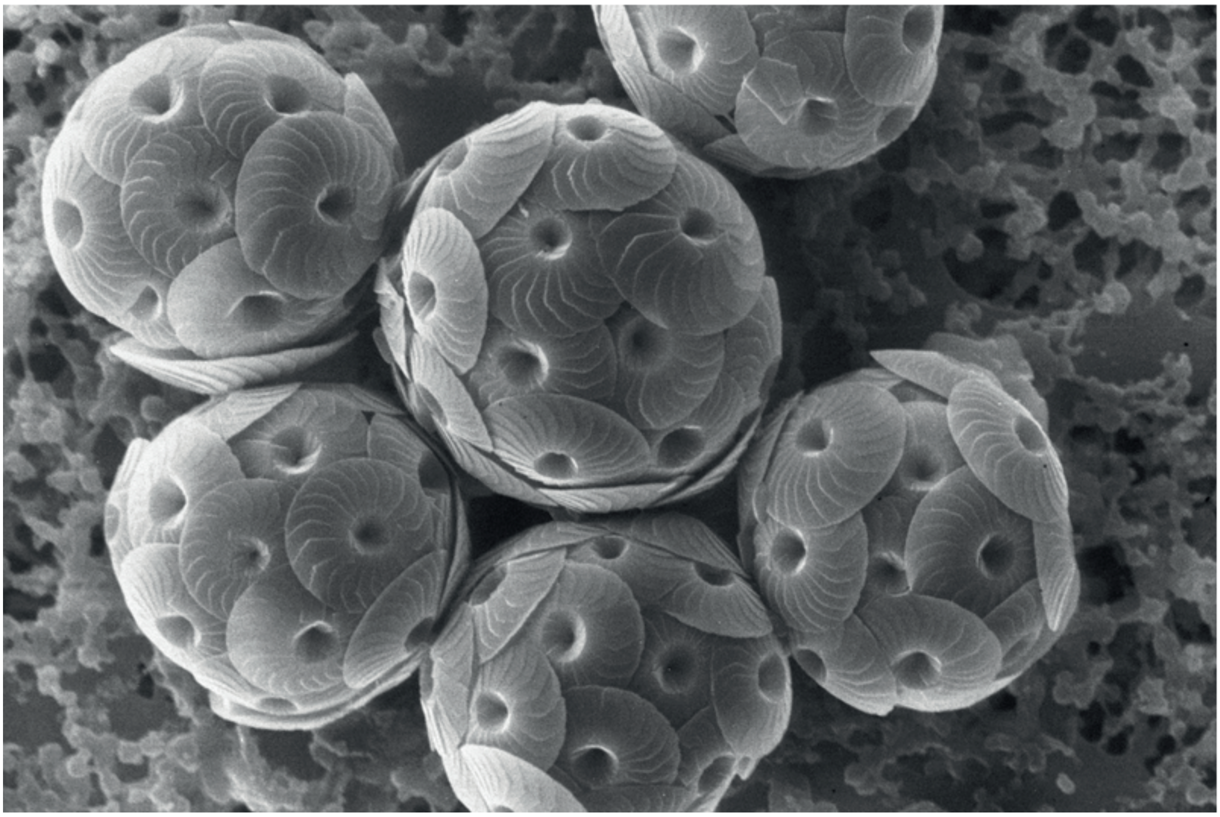
An acidifying ocean

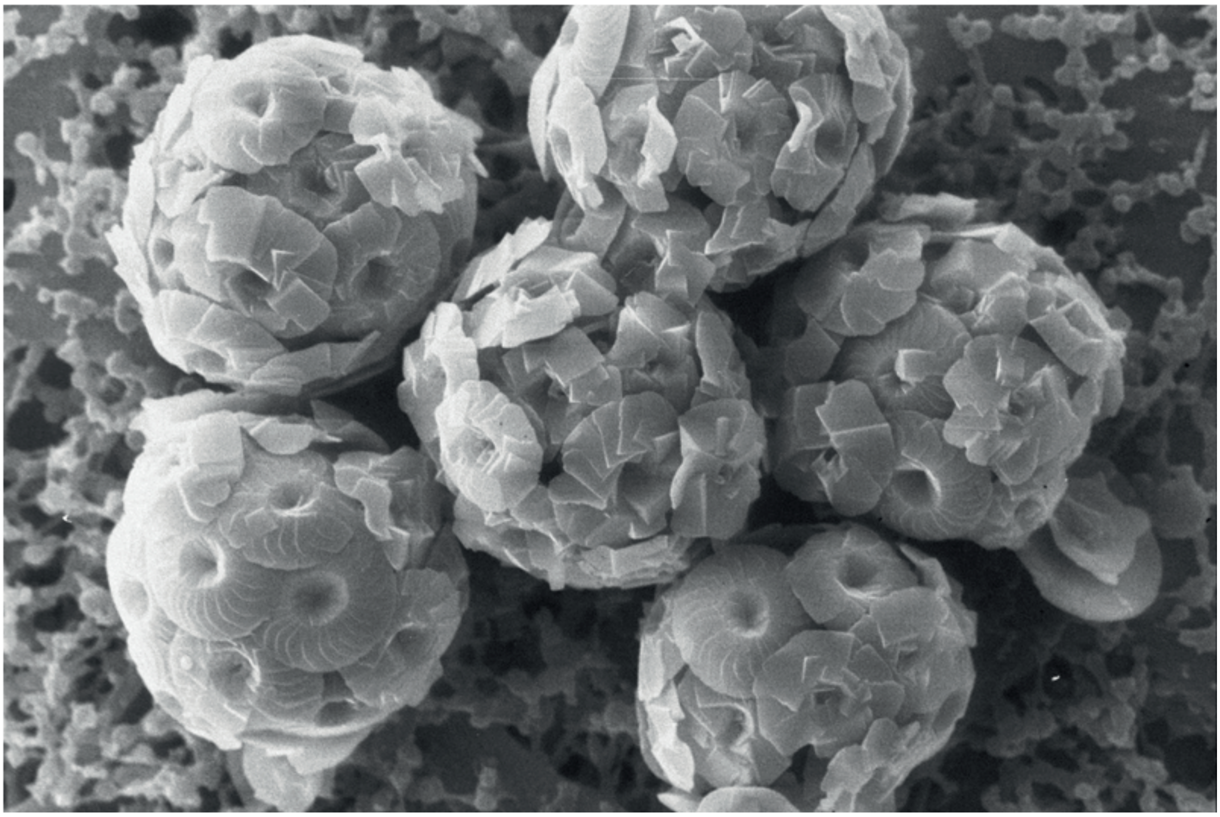
The ocean represents a net sink for the atmospheric carbon dioxide, absorbing an estimated 30% of anthropogenic emissions. A consequence of this is an acidification of near surface layers of the order of 0.1 pH units (about 30% more acidic) in the last century. For the "Moderate Mitigation" scenario: global oceanic pH is expected to decrease a further 0.12 units by 2099, with this change on the logarithmic pH scale representing an increase in acidity of about 30%. For the "Business as Usual" scenario: the pH decrease is projected to be 0.32 units by 2099, representing a doubling in acidity.

Projected percent change in aragonite saturation state (an ocean acidification indicator) in by 2100 under 'Moderate Mitigation' (top) and 'Business as Usual' (bottom) scenarios.



Erosion of calcium carbonate shells due to ocean acidification. Phytoplankton with normal levels of acidity (left) and those with acidity levels projected for the year 2100 (right). (Images: Ulf Riebesell, IFM-GEOMAR; Text: Koshland Science Museum, US National Academy of Sciences)



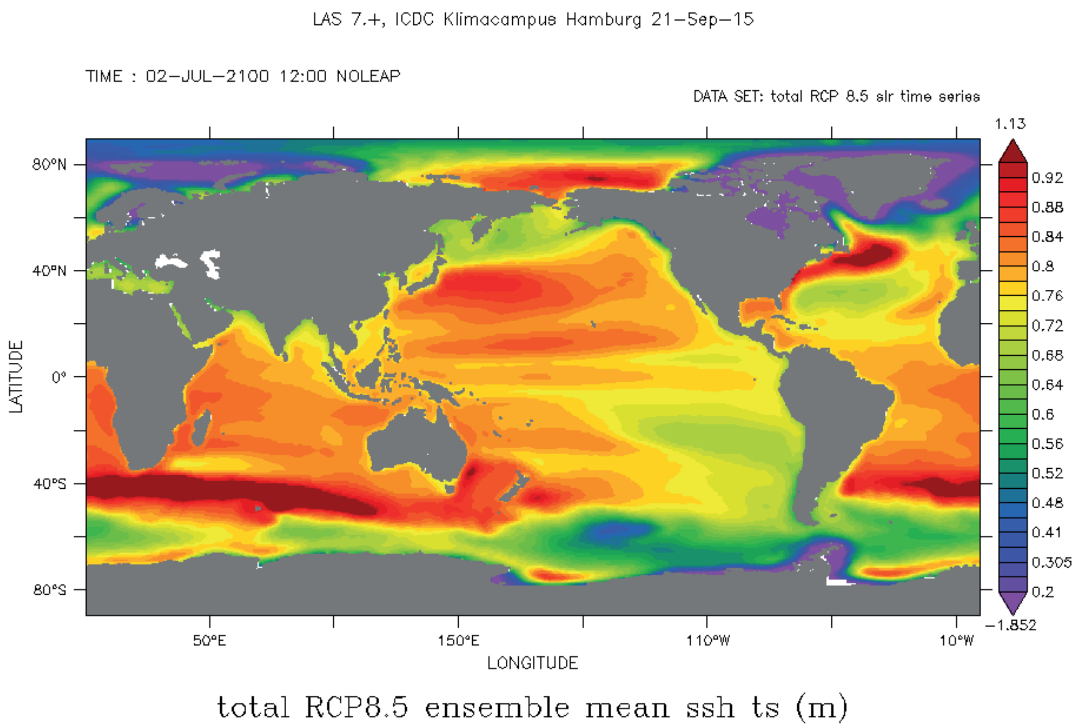


Rising sea level

In the last 30 years, tide gauges and satellite altimetry measures reveal a global sea level rise of approximately 3mm/year (the 20th century average was 1.7mm/year), integrating the effects of expansion from warming and additional ocean mass from melting land ice. Important regional effects are observed with sea level variations going from negative values over the Eastern Pacific to about four times the mean global value in the Indonesia-Philippines area.

In a warming earth, sea level will most likely rise for over 95% of the global ocean with areas near glaciers and ice sheets very likely to experience sea level fall (because land rises with the reduced weight of melting ice) by 2100. Greenhouse gases in the last 200 years have committed us to millennia of sea level rise. The pace and magnitude at which seas will permanently flood and reconfigure present-day coastal ecosystems will have profound consequences on human societies.

Projected sea level rise under the 'Business as Usual' scenario in 2100, showing the strong regional variation in the hazard. (University of Hamburg Integrated Climate Data Center Live Access Server at http://www.icdc.zmaw.de/las.getUI.do)



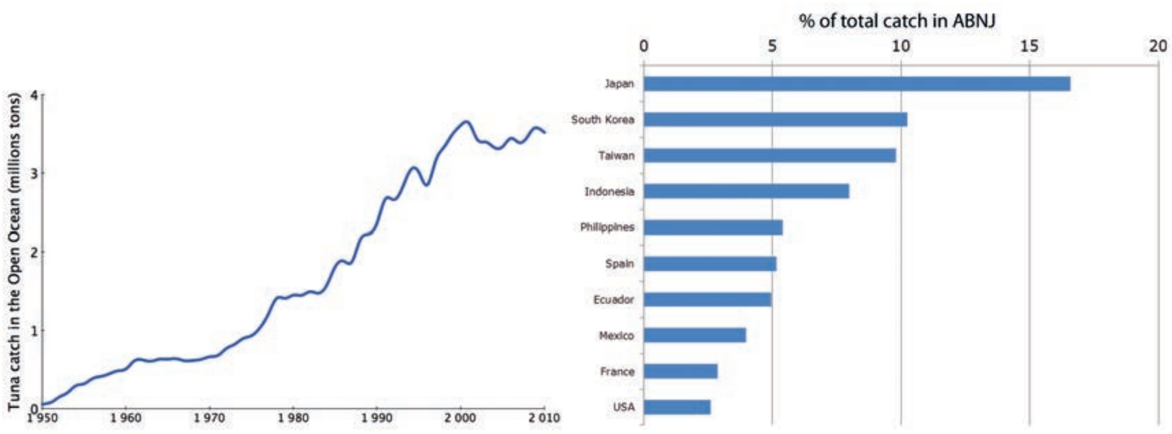
Increasing human impact on the open ocean

Fisheries exploitation is relentless and inequitably distributed

The world catch of tuna in the open ocean, taken beyond the exclusive economic zones of maritime countries, has increased from about 125 000 tons per year in the early 1950s to about 3.5 million tons from 2000 to 2010. It is not likely to increase much further. Most of this catch, consisting of skipjack, yellowfin, bigeye and albacore tuna is traditionally taken by Japan, South Korea and Taiwan, but other countries have been attempting to increase their share.

As the current states of tuna stocks in the open ocean and the effects of ocean warming preclude substantial further increase in catches, there will be increased competition among the subsided fleets of developed countries with distant-fishing fleets, and between established fleets and new entrants. Of these new entrants, three are developing countries (Indonesia, the Philippines and Mexico) appearing among the 10 countries with the largest tuna catch in the open ocean.

Tuna catch in Areas Beyond National Jurisdiction has increased enormously since 1950 (left). Over the period 2000-2010, the top ten countries (right) were fishing 70% of tuna in ABNJ.

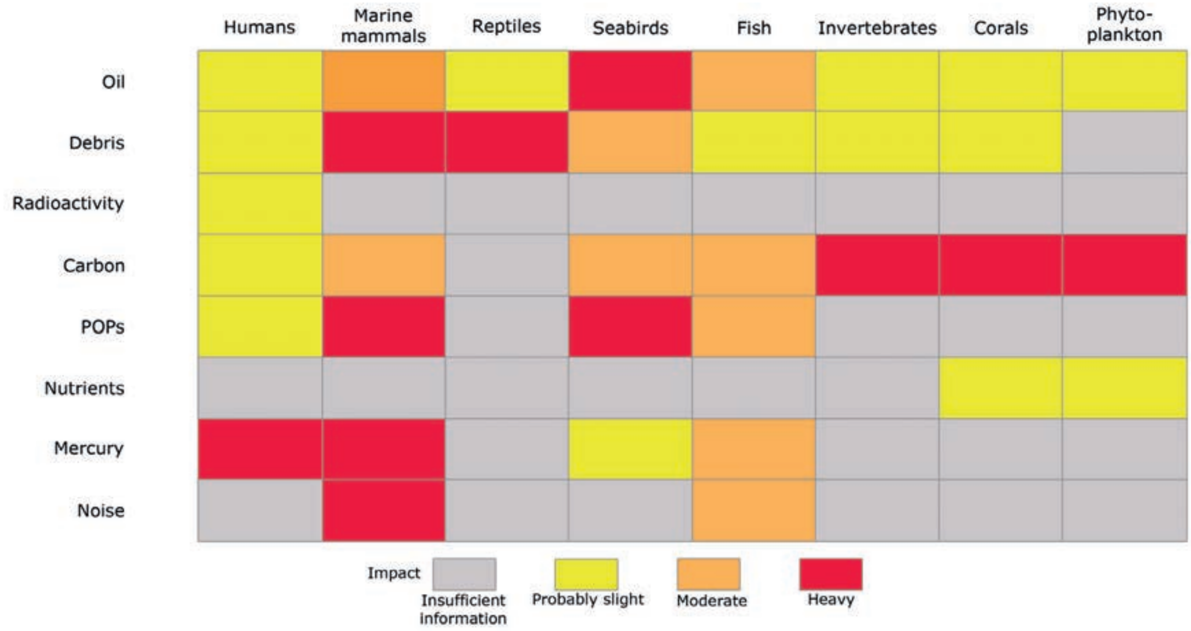


Open ocean pollution threatens ecosystems

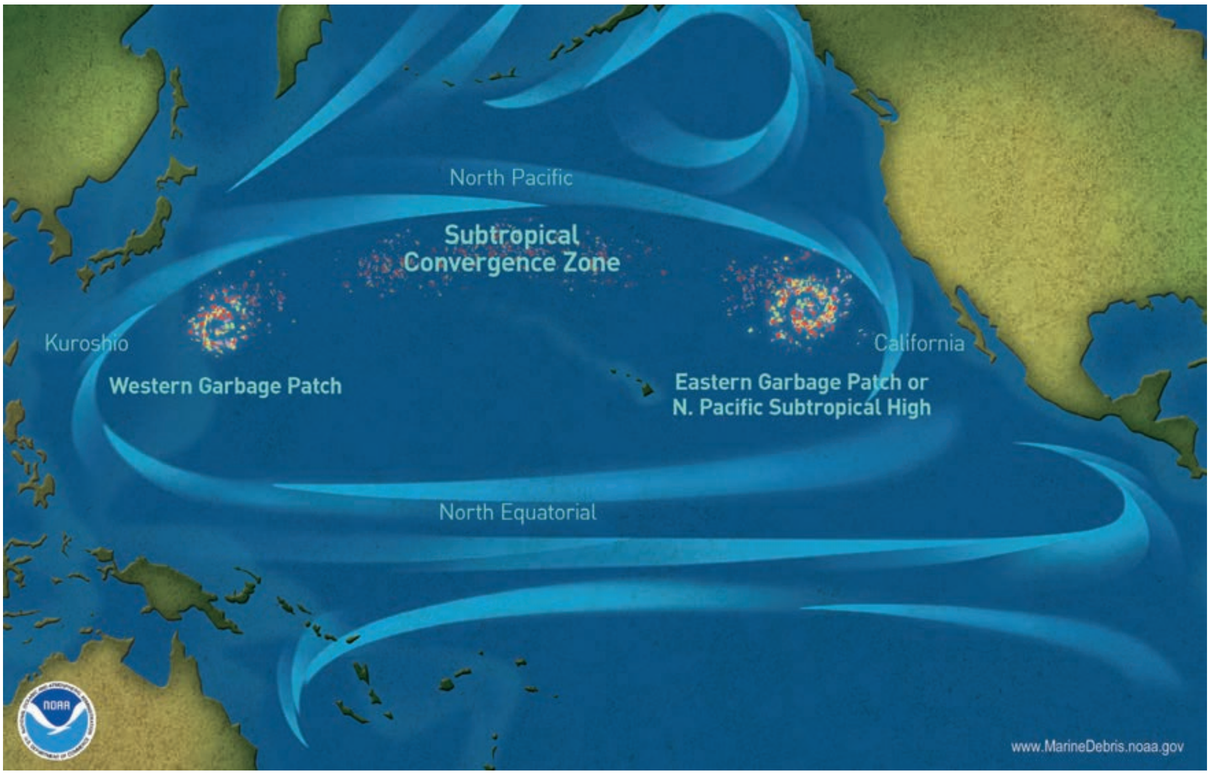
A review identifies issues affecting the open ocean that represent significant risks to ocean ecosystems, both now and in future. These are changes, directly or indirectly associated with human activities, threatening the integrity, biodiversity, productivity or sustainability of ocean sectors on large spatial scales.

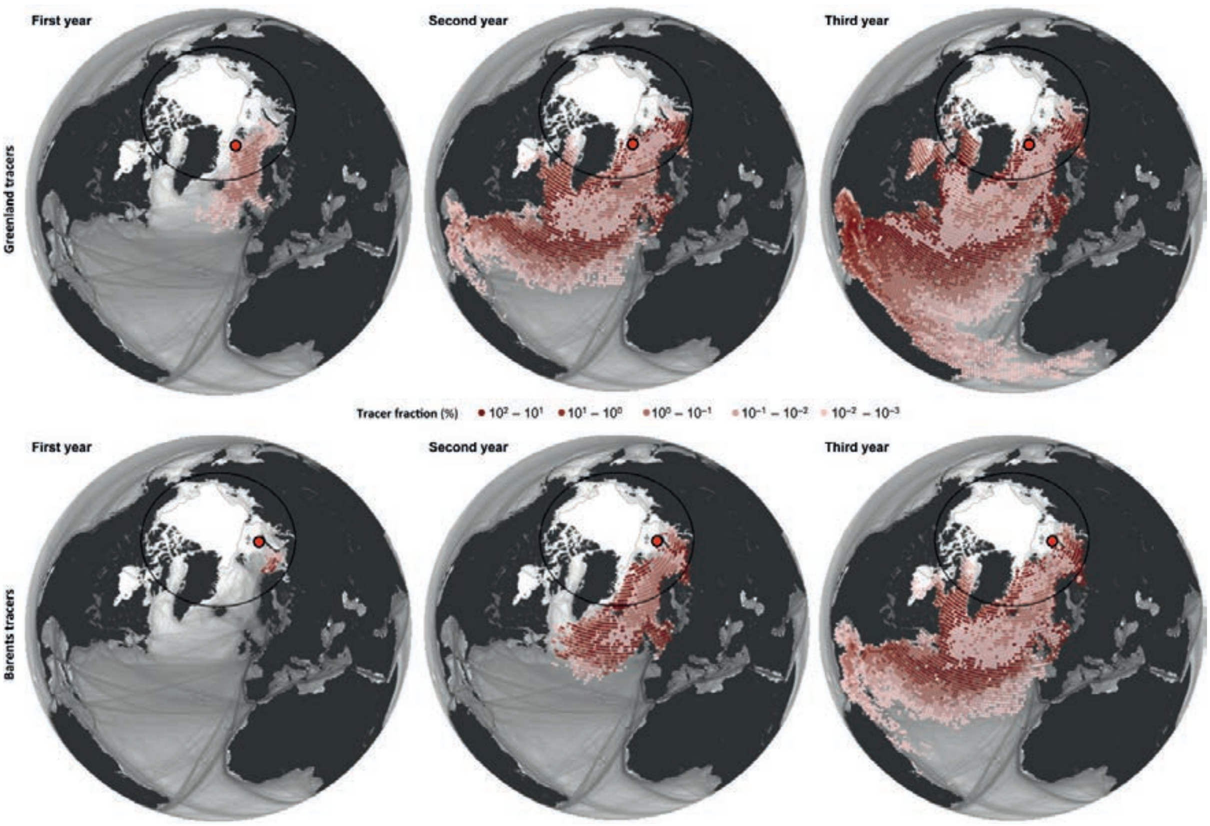
Atmospheric inputs of CO2 and nitrogen as well as solid debris (e.g plastics and netting) in the water column and on the seabed are a major concern. Pollution from the exploration/extraction of minerals and hydrocarbons from the deep-ocean seabed is a rapidly emerging threat. Contaminants are a real threat, but trends are unknown – a longer-term data time-series is needed. Greater investment in contaminant trend monitoring is urgently required.

Open ocean contaminants (rows) and their impact on different species and ecosystems (columns). While there is insufficient information about a number of the impacts, heavy impacts can be identified.

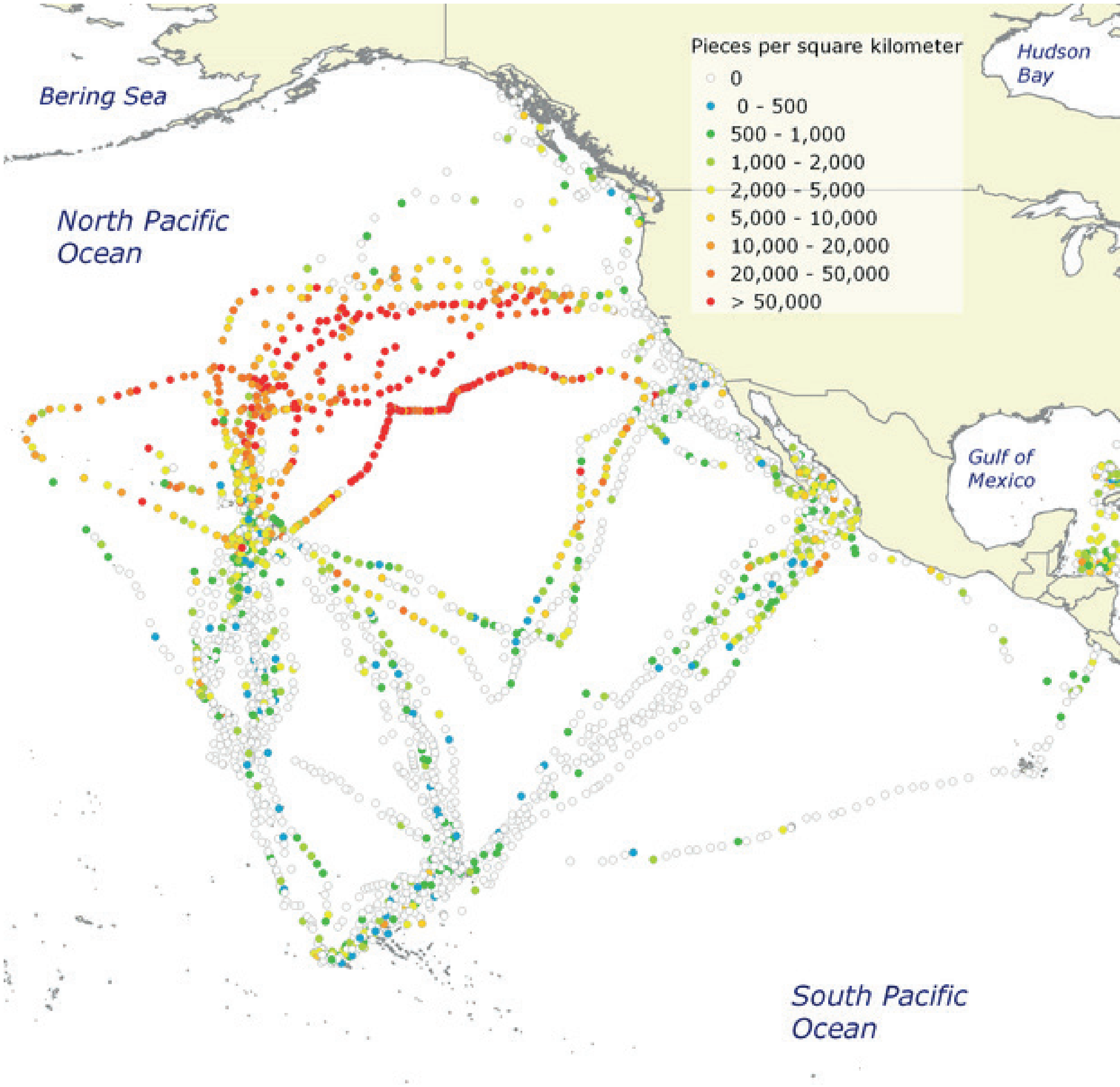


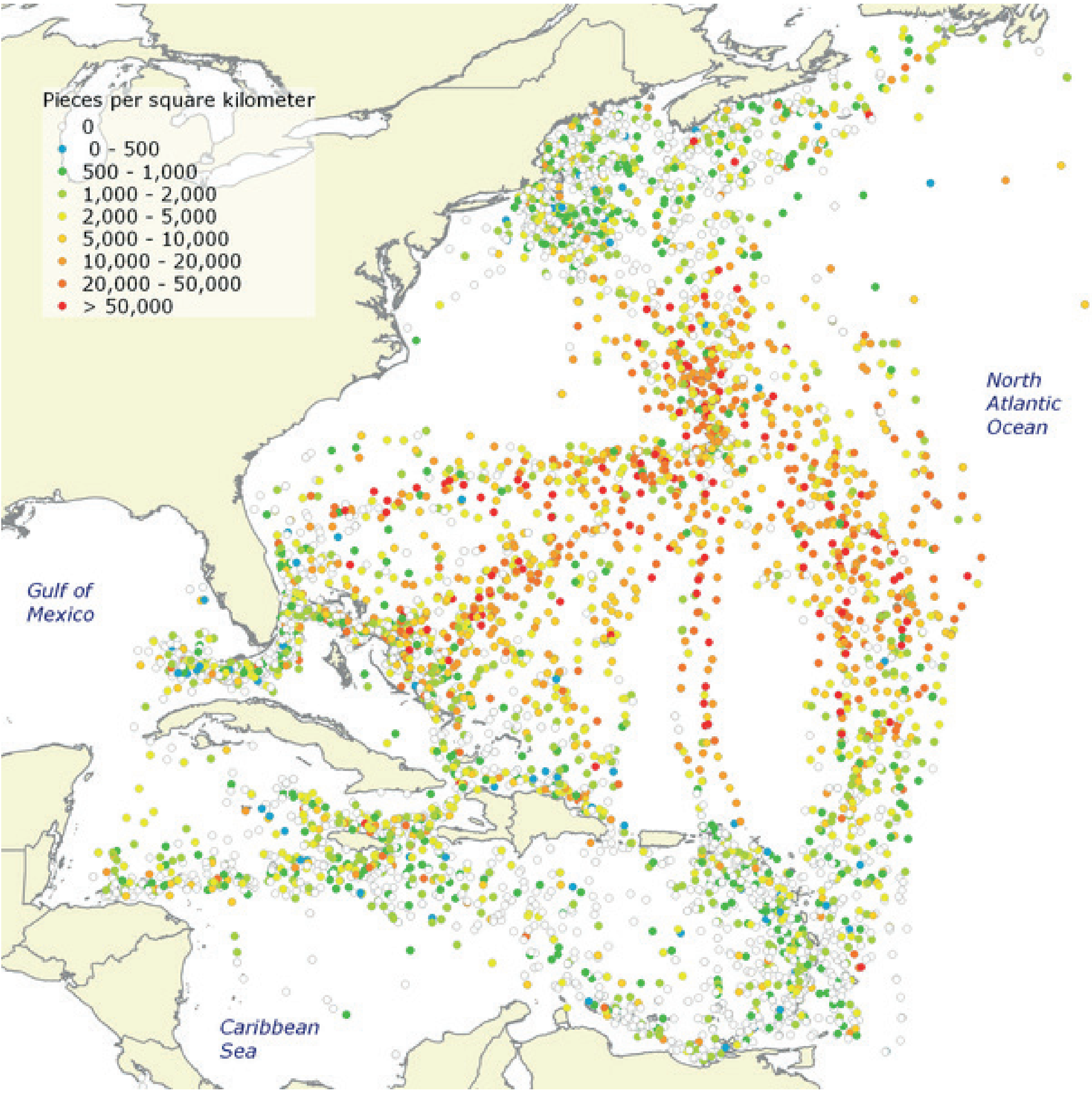
Marine debris aggregations in the Pacific Ocean include the Western and Eastern Garbage Patches and in the Subtropical Convergence Zone (top) (Credit: www.MarineDebris.noaa.gov). Similar aggregations have recently been located in the Greenland and Barents Seas (bottom) (Credit: Cozar et al. at https://doi.org/10.1126/sciadv.1600582, CCA-NC)



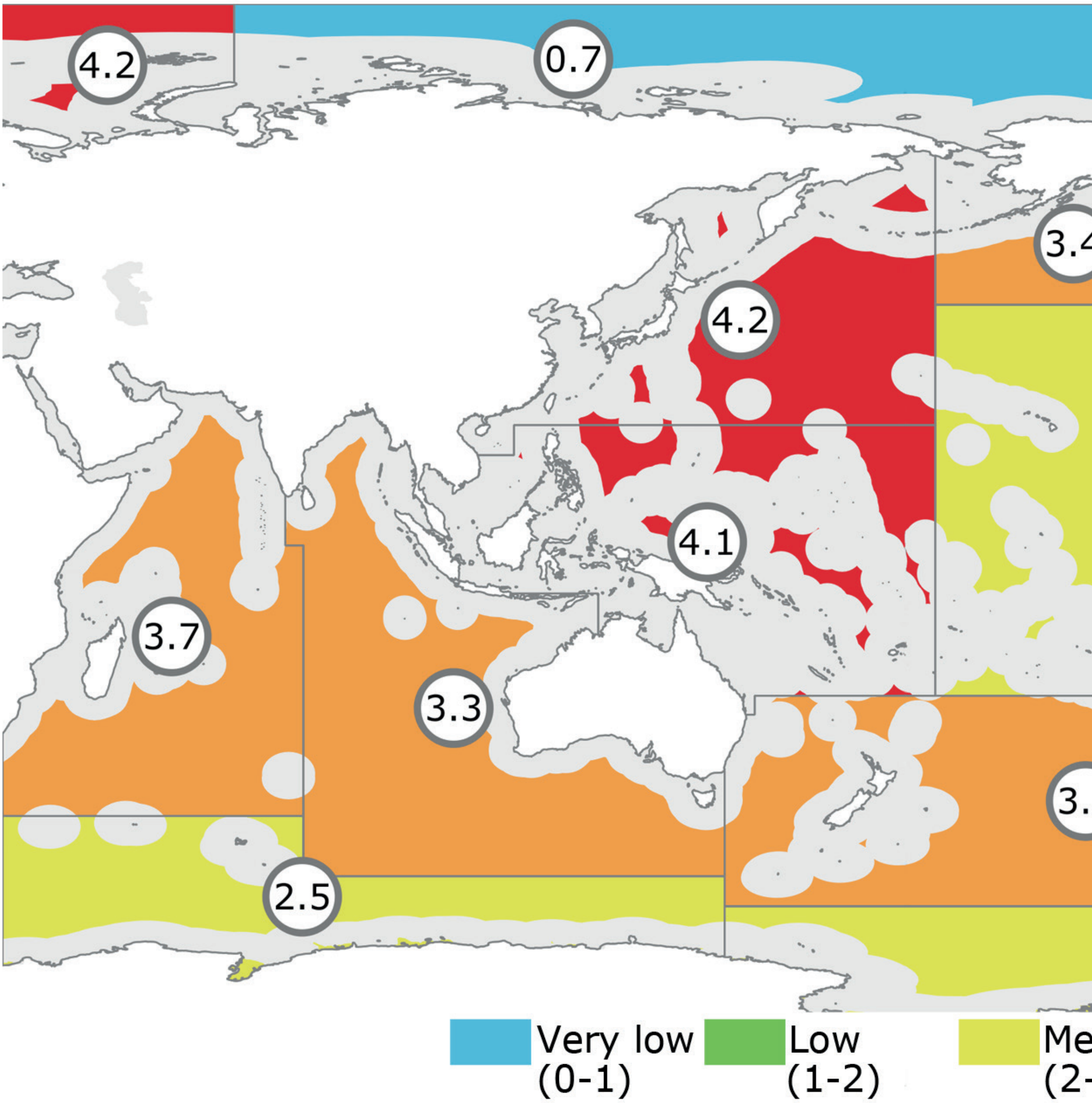


Density of floating microplastics (pcs km-2) per year in the eastern North Pacific for the period 1999-2010, left and in the western North Atlantic for the period 1986-2008, right. (Sea Education Association (SEA) Expeditions at http://onesharedocean.org/open_ocean/pollution/floating_plastics)




Pieces per square kilometer
0
0 - 500
500 - 1,000
1,000 - 2,000
2,000 - 5,000
5,000 - 10,000
10,000 - 20,000
20,000 - 50,000
> 50,000
North Atlantic Ocean
Gulf of Mexico
Caribbean Sea

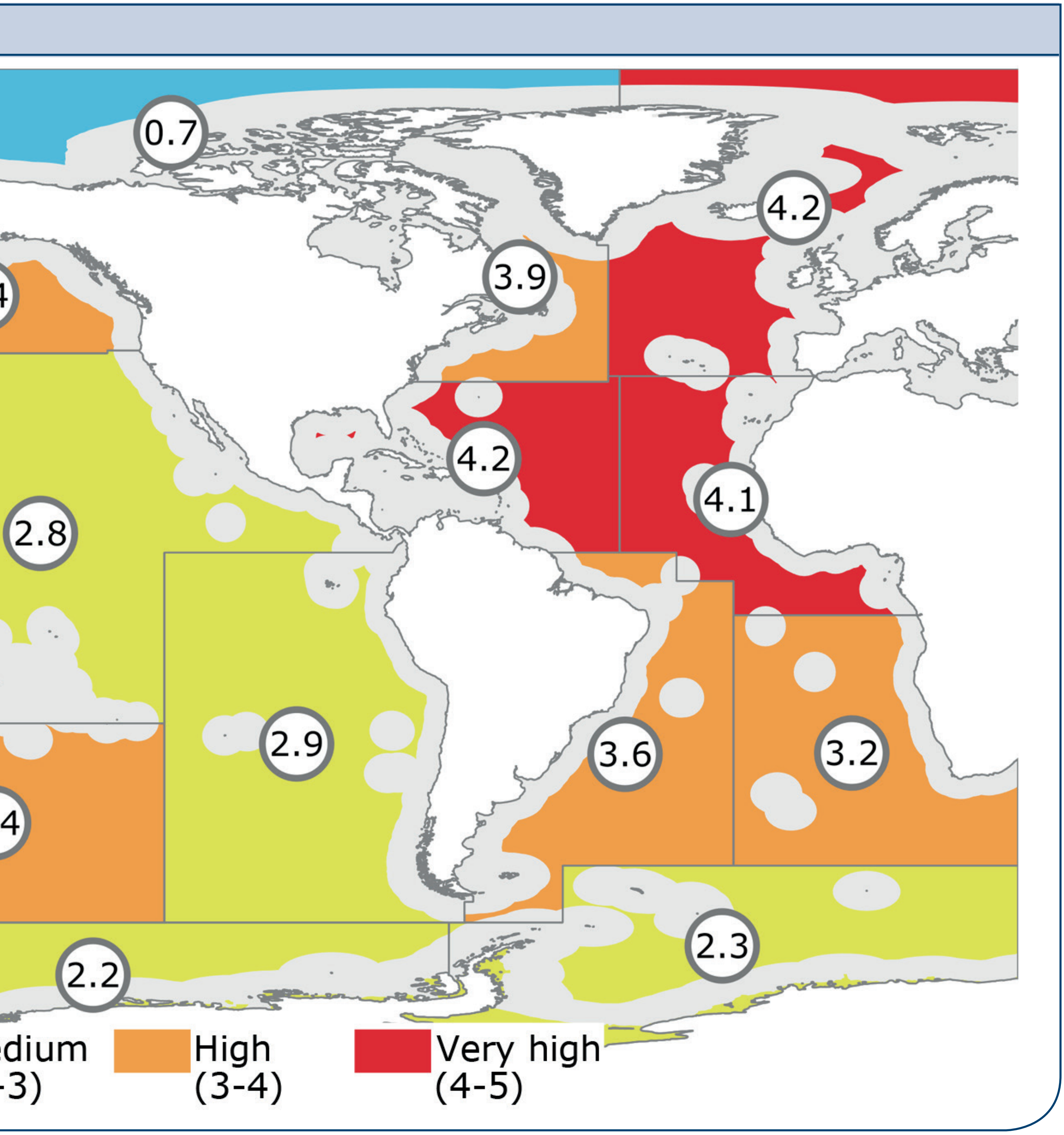
Cumulative human impact on ocean ecosystems in areas beyond national jurisdiction. This can be directly compared to the LME Assessment.



Many open ocean areas show strong cumulative human impact

Assessing and mapping the cumulative impact of human activities on marine ecosystems provides a unique perspective and understanding of the condition of marine regions, and of the relative contribution of different human stressors to creating that condition.

Stressors affecting open ocean regions largely fall into three main categories: climate change, commercial fishing, and commercial activity (such as shipping).



Stressors associated with climate change, most notably ocean acidification and increasing frequency of anomalously high sea surface temperatures, are the top stressors for nearly every high seas region.

The most heavily human-impacted High Seas regions are the northern and central Atlantic and the northwest and western central Pacific. The least impacted region is the Arctic

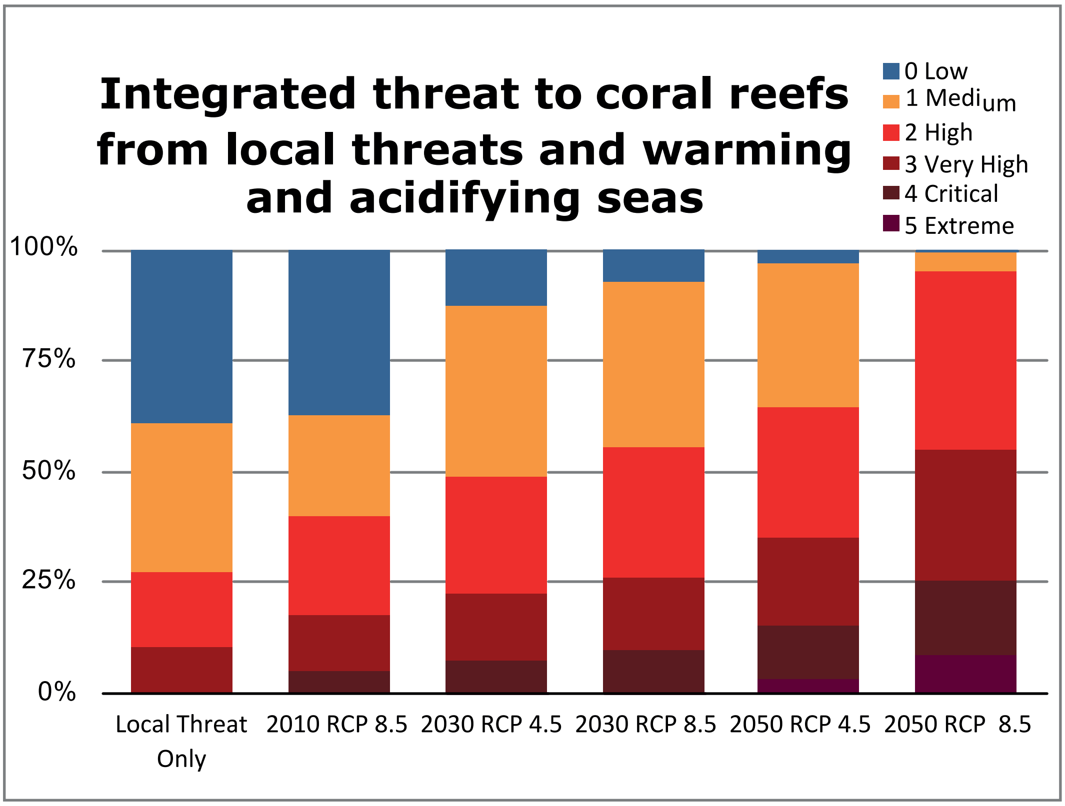
Coral reefs at increasing risk

Despite their value to humans for food, livelihood, recreation and coastal protection, coral reefs face severe local and global threats. At present, over 60% of the world's coral reefs are threatened by local activities, with over one quarter at high or very high threat. When the influence of warming seas and ocean acidification for the current decade are considered, the percentage of reefs rated as threatened increases slightly, but the proportion of reefs at high, very high or critical threat levels increases to 37%.

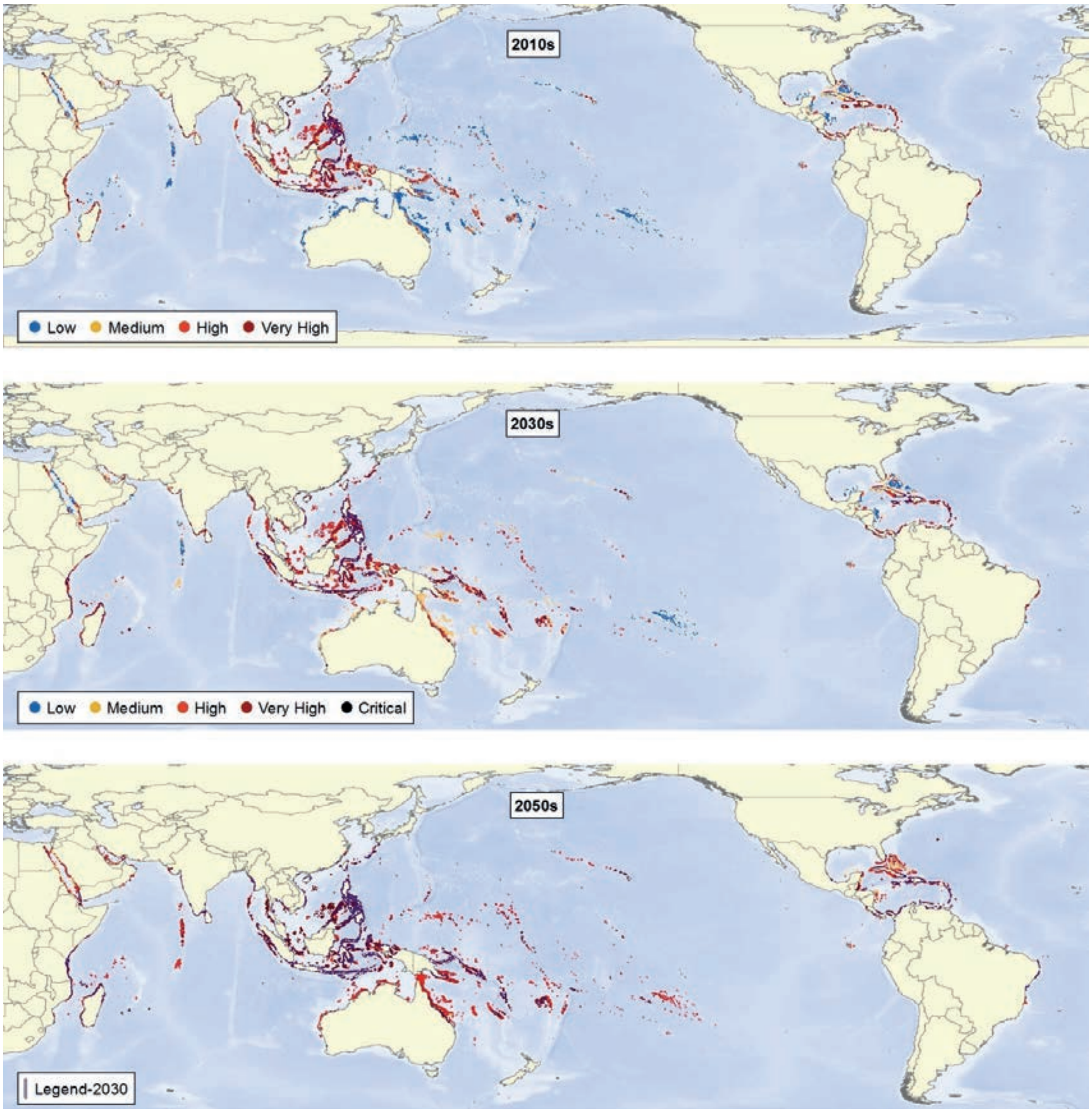
Threat to coral reefs will increase in the coming decades due to continued greenhouse gas emissions driving ocean warming and acidification. Using projections of ocean warming and acidification, estimates suggest that in the 2030s about 90% of the world's coral reefs will be threatened, and by the 2050s virtually all reefs will be threatened by the combined (integrated) pressures from local and global hazards. The proportion of integrated threat coming from global sources (warming and acidification) is estimated to be 20 % in the current decade, 40-45% in the 2030s, and between 55 and 65% in the 2050s.

Future emissions of greenhouse gases will greatly influence the severity of that threat. Under the "Business as Usual" scenario, 95% of reefs are projected to be in areas rated as under at least high threat (with 55% in the very high, critical or extreme categories). Under the "Moderate Mitigation" scenario, projections suggest 55% of reefs are under at least high threat (with 35% in the very high, critical or extreme categories).

Integrated threat to coral reefs from local threats, warming and acidification under "Business As Usual" emission scenario (RCP 8.5) and "Moderate Mitigation" scenario (RCP 4.5) in 2030s and 2050s.



Integrated local and global threats to the world's coral reefs under the "Business as Usual" (RCP 8.5) scenario in 2010s, 2030s and 2050s.

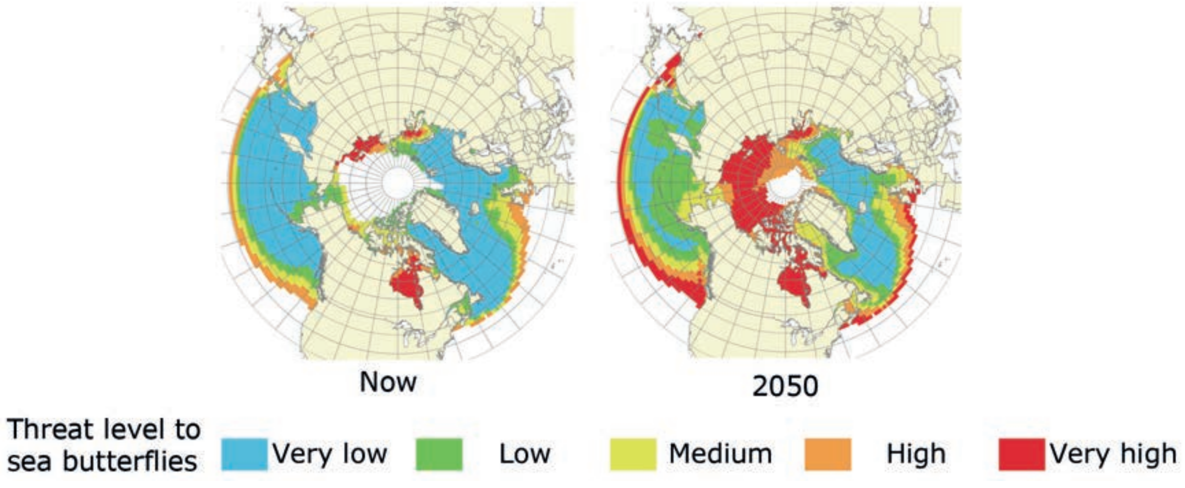


Habitats are being squeezed

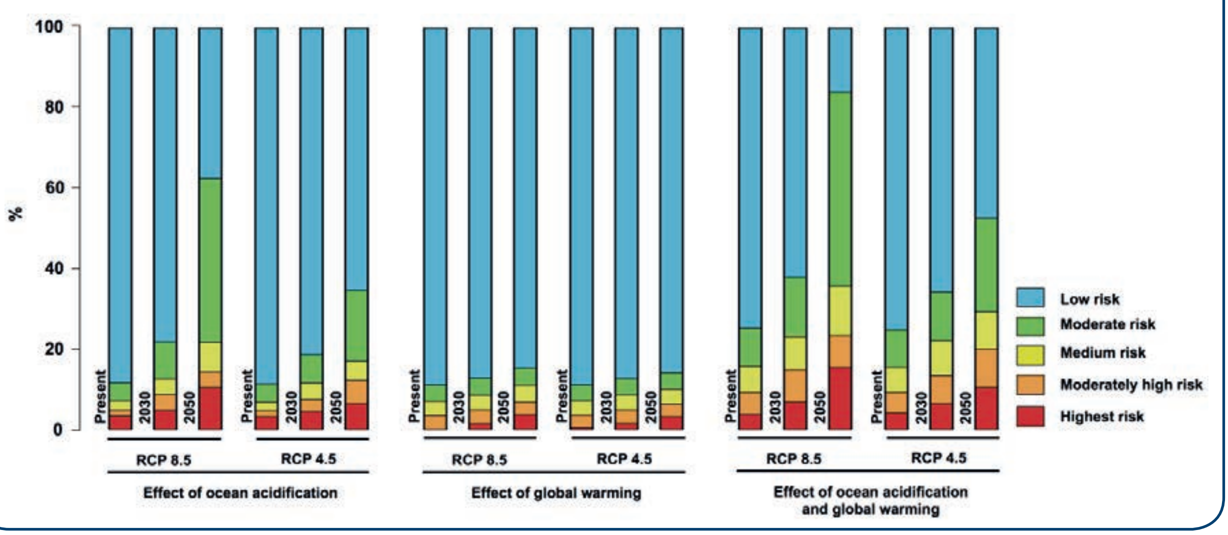
Pteropods, or 'sea butterflies', are tiny snails that play a critical role in various ecosystems as prey for a variety of predators. There is a great concern about the potential impact of global change – and particularly ocean acidification – on these organisms, as their shells are sensitive to changes in ocean chemistry.

Global change is a very serious threat for high latitude pteropods, as by 2050 under the 'Business as Usual' scenario, they likely will not be able to thrive in most of the Arctic Ocean and some regions of the Southern Ocean.

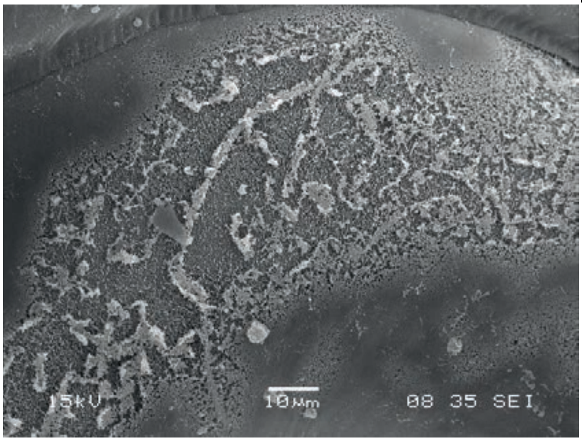
Current and projected threats based on the combined effects of ocean acidification and global warming on the Arctic pteropod Limacina helicina under the "Business as usual" emission scenario (RCP 8.5).



Percentage of the area of distribution of the L. helicina exposed to the different risk indicators. Risk indicators were created for the effect of ocean acidification alone (decreasing uaragonite), the effect of global warming alone (temperature) and the effects of global change (combination of ocean acidification and global warming).



A healthy pteropod *(Limacina helicina)* (top) ; an individual with dissolving shell (right); an image taken by a scanning electron microscope showing extent of shell dissolution (below). The pteropod samples were collected during cruises by NOAA off the US West in 2011 and 2013. All photos by NOAA.



Fish catch potential is decreasing

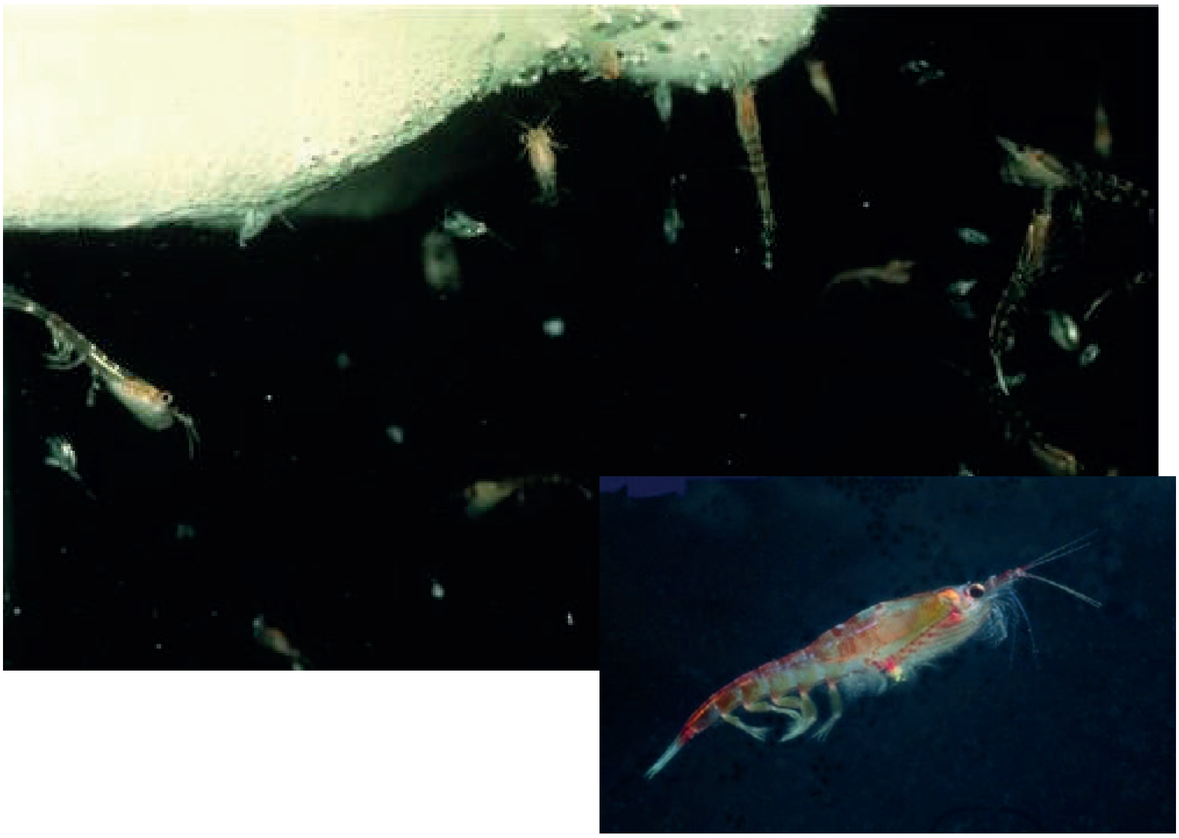
Marine fisheries productivity is likely to be affected by the alteration of ocean conditions including water temperature, ocean currents and coastal upwelling, as a result of climate change.

The open ocean will be increasingly impacted by climate change, as will coastal areas of the ocean. These changes are here modeled using a bioclimate envelope model capable of reproducing and amplifying the observed poleward migration of fishes exploited by fisheries. The results are an overall predicted reduction of 20 % of the potential catch of the open ocean to 2030 and 34 % to 2050.

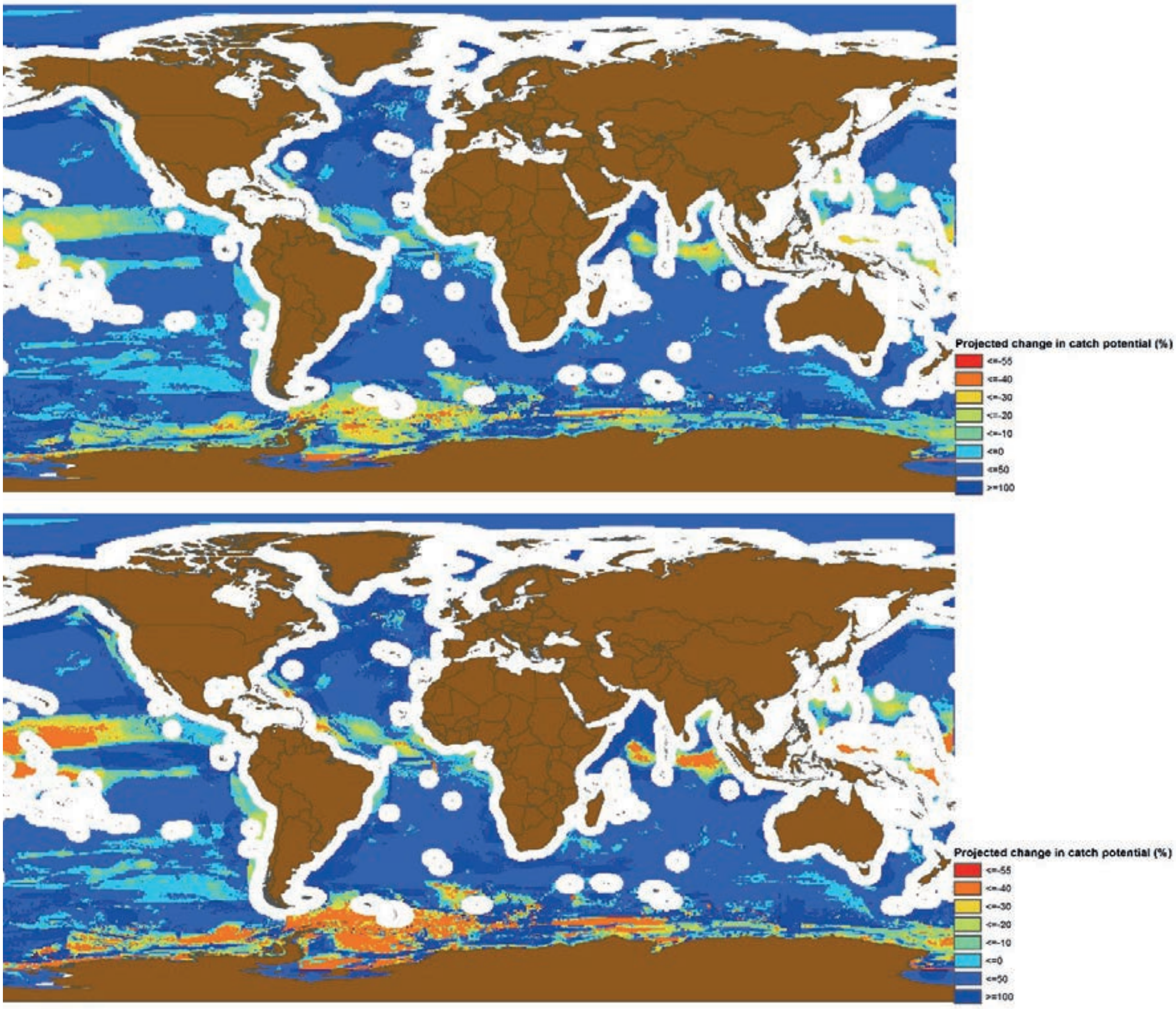
The strongest declines of potential catch should occur in two places:

- the inter-tropical belt, because increasing stratification will depress primary and secondary production and because no fish will replace those tropical fish that migrate poleward, and
- Antarctica, because the life cycle of the currently abundant krill (*Euphausia superba*) is tied to shelf ice that is expected to melt away.

Antarctic krill, *Euphausia superba*, feeding at the ice edge, top (Southwest Fisheries Science Center, NOAA Fisheries Service). Close up of *E. superba*, right (World Register of Marine Species Image, CC BY-NC-SA 4.0).



Change in projected catch potential (%) under "Business as usual" emission scenario (SRESA2) in the 2030s (top) and in the 2050s (bottom).



Changing biodiversity in the global ocean

Biodiversity is our natural capital, our life insurance. Understanding how much the ocean impacts us and how we impact the ocean is critical to managing our world. Knowledge of ocean biodiversity is highly variable: there is much more data from recent decades, and some areas of the world are far better studied than others. Over 99 per cent of Earth's habitable space is marine, yet for 99 per cent of this vast realm we lack the basic biodiversity knowledge required for effective management.

According to the Red List of the International Union for Conservation of Nature (IUCN), 17 per cent of marine species assessed are considered to be threatened with extinction and 20 are extinct. When plotted in OBIS, areas of greatest importance to species known to be threatened include the Caribbean and Atlantic Coast of the USA, waters between Eastern Africa and Madagascar, and the Indo-Pacific. However, considering that little is known of rare species, true rates of threat in marine species may be substantially higher, and spatially more distributed, than current estimates suggest. In addition, OBIS lists almost 500 species that have >10 observations but have not been recorded at all in the last 50 years.

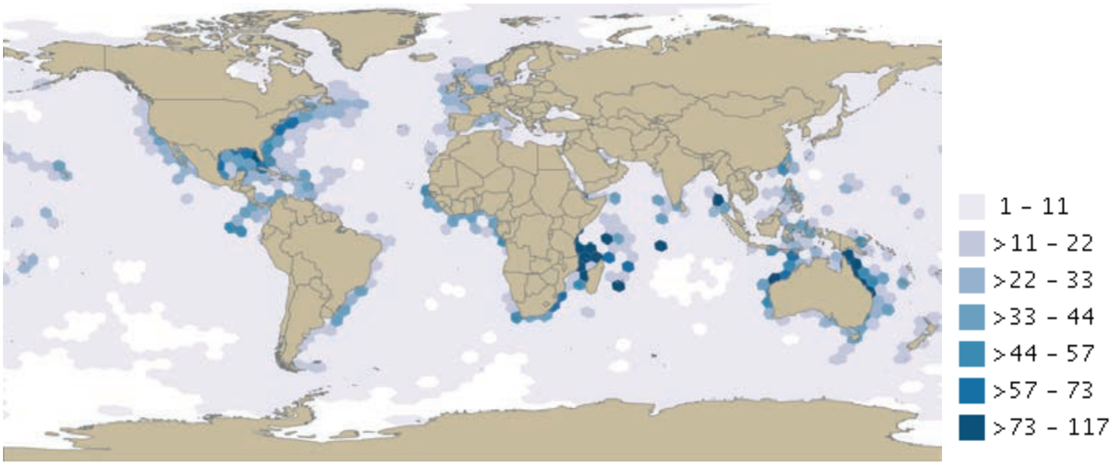
Monitoring ocean biodiversity is expensive and can be risky, and requires highly skilled people. Very few marine regions or taxonomic groups have benefitted from long-term monitoring programs; hence stocktaking remains far from complete. Publishing existing biodiversity data into open data repositories such as OBIS provides the most cost-effective means to address this shortfall, and we hope that momentum in this direction can be maintained, alongside new efforts to discover and document the diversity and distribution of life in the ocean. In addition, we recommend focused efforts to monitor the abundance of key species at all trophic levels, potentially as part of a global initiative such as the Global Ocean Observing System (GOOS).

A recent comprehensive inventory of threats across 24 key global ocean areas was provided by the Census of Marine Life (PLoS One, 2010). Briefly, overfishing, habitat loss, and pollution are the greatest threats to biodiversity in all regions, followed by invasive species and impacts of climate change. Establishing biodiversity baselines requires that recent declines and extinctions of marine species due to these pressures are quantified.

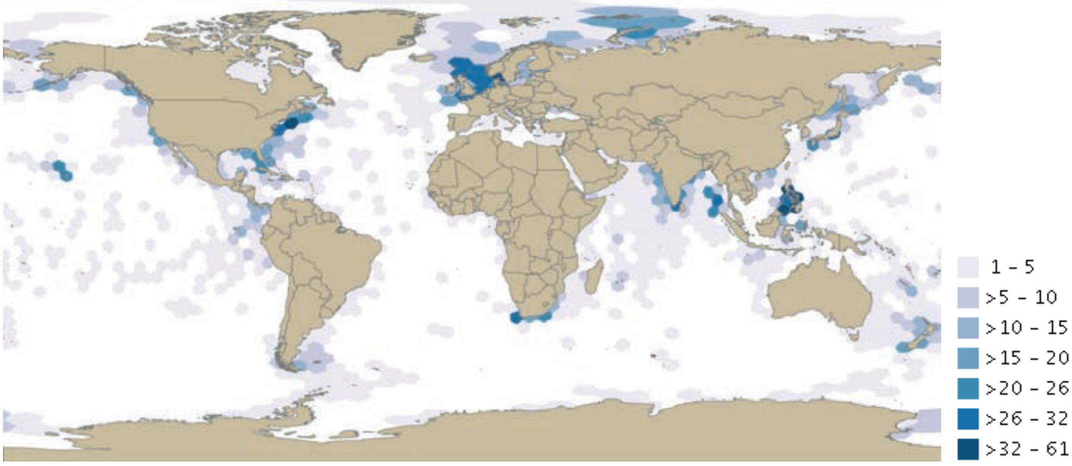
Only 4 per cent of described marine species (9,554 out of 230,000) have been assessed by the IUCN, of which 2,730 (29 per cent) are rated as Data Deficient (DD), too poorly known to assign to an IUCN category. Of the remaining 6,824 species, 1,194 (17 per cent) are considered to be threatened with extinction (IUCN categories Vulnerable VU, Endangered EN or Critically Endangered CR) and 20 are extinct. For the best-known taxonomic groups, rates of extinction risk across assessed species average 20-25 per cent (Webb and Mindel, 2015).

Areas of greatest importance to species known to be threatened (IUCN categories VU, EN, and CR) include the Caribbean and Atlantic Coast of the USA, waters between Eastern Africa and Madagascar, and the Indo-Pacific (Figure 5.42). However, given that DD species often have characteristics typical of threatened species (Pimm et al. 2014, Dulvy et al. 2014) and may occur in different regions from species known to be threatened (Pimm et al. 2014), true rates of threat in marine species may be substantially higher, and spatially more distributed, than current estimates suggest.

Global map showing the number of threatened species per hexagonal grid cell of c. 200,000 km2 following the IUCN Red List Species categories EN (endangered), CR (critically endangered) and VU (vulnerable) based on species distribution records from OBIS.



Global map showing the number of "pseudo-extinct" species per hexagonal grid cell of c. 200,000 km2, i.e. those with <10 records in OBIS but not observed anymore in the past 50 years.



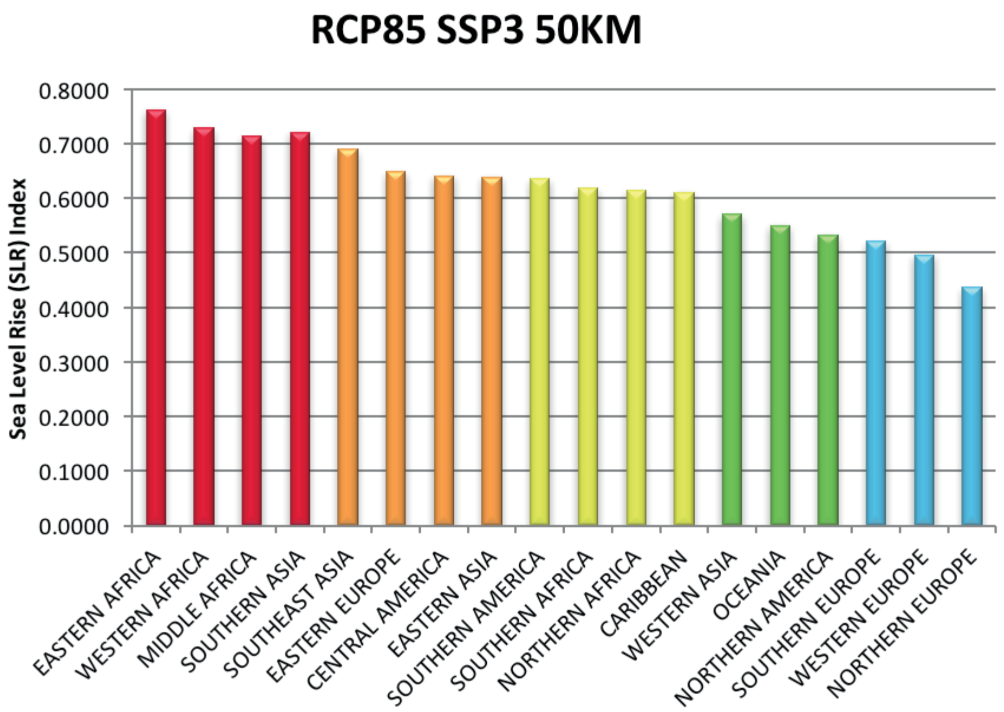
Direct sea level rise (SLR) risk to coastal communities grows

The risk of sea level rise (SLR) in 2100 was estimated within a framework of hazard, exposure and vulnerability using internally consistent future development scenarios (or pathways) for 139 coastal countries over the time period 2010-2100.

While sea levels (hazard), total land area and people living in the 50-km coast (exposure) and vulnerability (HDI gap) contribute equally to risk, vulnerability influences risk very significantly with 80% correlation across development pathways.

- Countries that will experience highest sea levels (highest degree of hazard), on average across scenarios are: the USA, Canada, Russia, South Africa and Mozambique (tied), Japan, Australia and New Zealand (tied), Madagascar and Mauritius, in decreasing order.
- Averaged across the five future scenarios, the countries with the highest degree of exposure are: USA, Indonesia, China, Brazil, Viet Nam, Nigeria, Bangladesh, Egypt and Australia, in decreasing order.
- Using the HDI Gap as vulnerability metric, the most vulnerable countries, on average across the five scenarios are: Somalia, Mozambique, Sierra Leone, Liberia, Madagascar, Guinea-Bissau, Solomon Islands, Eritrea, Papua New Guinea and Benin, in decreasing order.
- The ten countries most threatened by SLR indicated by the SLR Risk Index, on average and across the five reference projection pathways (in decreasing order) are: Somalia, Mozambique, Madagascar, Angola, Liberia, Sierra Leone, Papua New Guinea, Senegal, Guinea-Bissau and Mauritania. Seven of these coastal states are identified among the most vulnerable.

The relative regional risk to sea level rise in 2100 under the 'Business as Usual' (RCP8.5) emissions scenario and the 'Stalled Development' (SSP3) socioeconomic pathway.



Top thirty coastal countries at highest risk to sea level rise. Their mean ranks for hazard (averaged over RCP4.5 and RCP 8.5), exposure, vulnerability and sea level rise (SLR) Risk Index (averaged over 5 development scenarios) are shown. Risk colors are red (very high risk), orange (high risk), yellow (moderate risk), green (low risk), and blue (very low risk.

COUNTRY	AVERAGE HAZARD RANK	AVERAGE EXPOSURE RANK	AVERAGE VULNERABILITY RANK	AVERAGE SLR RISK RANK
Somalia	19	66	1	**1**
Mozambique	4	19	2	**2**
Madagascar	9	29	5	**3**
Angola	19	21	11	**4**
Liberia	60	42	4	**5**
Sierra Leone	58	43	3	**6**
Papua New Guinea	19	37	9	**7**
Senegal	71	25	16	**8**
Guinea-Bissau	67	56	6	**9**
Mauritania	82	31	13	**10**
Tanzania	60	34	19	**11**
Benin	50	55	10	**12**
Myanmar	89	15	24	**13**
Guinea	76	41	20	**14**
Nigeria	41	7	43	**15**
India	44	4	45	**16**
Togo	33	93	14	**17**
Yemen	46	58	22	**17**
Congo Dem	28	99	12	**19**
Cameroon	50	68	26	**20**
Solomon Islands	16	103	7	**21**
Indonesia	11	2	61	**22**
Ghana	40	51	31	**23**
Pakistan	120	28	23	**24**
Gabon	25	35	41	**25**
Congo Rep	37	59	31	**26**
Viet Nam	62	6	49	**27**
Eritrea	104	91	8	**28**
Cambodia	87	76	27	**29**
Bangladesh	113	8	42	**30**

About 155,000 live in 5.8 km2 of coral atoll land, with an elevation of 2.4 m in Male, the capital city of the Republic of Maldives. Sea level is currently rising at 0.8 to 1.6 mm per year. By the close of the century, Maldives is projected to lose 77% of its land area assuming a moderate sea level rise of 0.5 m. (Photo credit: Shahee Ilyas, CC Attribution-Share Alike 3.0 Unported.)

Changing health of the ocean

People value ocean ecosystems for the food they provide, the aesthetic beauty they carry, the livelihoods they support, and the existence and vast diversity of species within them. Even though the relative importance of each of these benefits varies from person to person, their value is nearly universal. The ocean enriches our lives in many ways, but the sustainable delivery of these benefits is jeopardized when ocean health is compromised.

Although the high seas are rarely visited by people, they support key goals people have for the ocean, most notably food provision through wild-caught fisheries and the iconic and existence value of species. To fairly assess the condition, or health, of the high seas, one must measure the status of all relevant goals achieved from high seas ecosystems.

The OHI tracks the current status and expected future condition of these human values for ocean ecosystems. It does this by assessing the cumulative stressors on ecosystem services and tracking the resulting status of the sustainable delivery of services to people. It also incorporates measures of governance as a means of quantifying the potential resilience of the system. As such, the Index directly captures stages 4-6 in the Conceptual Framework (see Introduction) and indirectly stages 1a and 3, thus spanning both the human and natural systems. In combination with cumulative human impact (CHI) assessments, which directly measure the connection between stages 3 and 4, ecosystem service valuations, and more comprehensive governance assessments, a complete picture of high seas condition emerges.

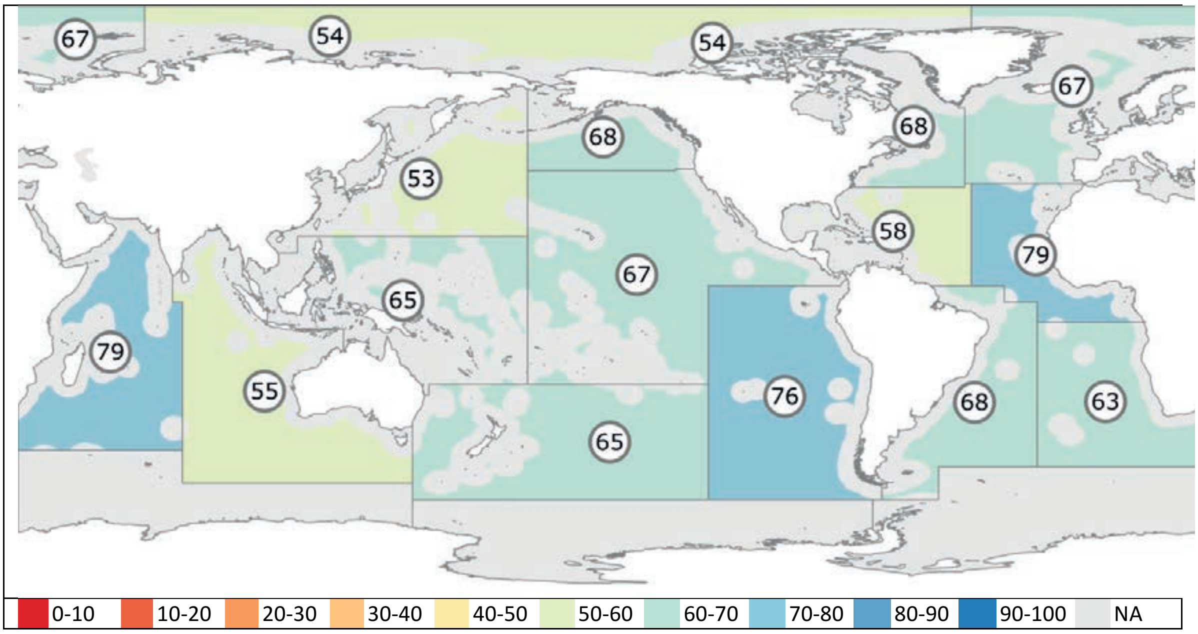
Overall Index scores varied from 53 to 79, with an average regional score of 66 and an area- weighted total high seas score of 67 (Figure 8.2). The highest scoring regions were the Western Indian Ocean (79), the Eastern Central Atlantic (79) and the Southeast Pacific (76), while the lowest scoring regions were the Pacific Northwest (53), Arctic Sea (54), and Eastern Indian Ocean (55; see Table 8.3). These scores suggest a lot of room for improvement in ocean health – substantial room in the lowest scoring regions – but also that some dimensions of ocean health are faring better (described below). In general, high seas regions scored lower than EEZ regions globally, except for species biodiversity, which scored slightly higher in the high seas (Table 8.3).

Managing high seas regions will benefit greatly from coordination with surrounding countries. For many issues, this will require agreements by UN member states on how to regulate areas beyond national jurisdiction (ABNJ). Because relatively few goals are relevant to or can be assessed in the high seas, the status of fisheries and biodiversity drive Index scores in these regions. As such, meaningful management aimed to improve overall ocean health needs to focus on improving fisheries management, particularly for migratory and wide-ranging stocks that influence fisheries scores for multiple high seas regions, and mitigating threats to biodiversity, in particular climate change. There is also urgent need to increase and improve monitoring of the high seas so that future assessments will be more comprehensive.

Name, abbreviation (in parentheses) and definition of each goal and sub-goal of the Ocean Health Index. Only those goals and sub-goals marked with an * were assessed for the high seas.

Goal	Sub-goal	Definition
*Food provision (FP)	*Fisheries (FIS)	Harvest of sustainably caught wild seafood
	Mariculture (MAR)	Production of sustainably cultured seafood
Artisanal fishing opportunity (AO)		Opportunity to engage in artisanal-scale fishing for subsistence and/or recreation
Natural products (NP)		Sustainable harvest of natural products, such as shells, algae, and fish oil used for reasons other than food provision
Carbon storage (CS)		Conservation status of natural habitats affording long-lasting carbon storage
Coastal protection (CP)		Conservation status of natural habitats affording protection of the coast from inundation and erosion
Tourism & recreation (TR)		Opportunity to enjoy coastal areas for recreation and tourism
Coastal livelihoods & economies (LE)	Coastal livelihoods (LIV)	Jobs and wages from marine-related sectors
	Coastal economies (ECO)	Revenues from marine-related sectors
*Sense of place (SP)	*Iconic species (ICO)	Cultural, spiritual, or aesthetic connection to the environment afforded by iconic species
	Lasting special places (LSP)	Cultural, spiritual, or aesthetic connection to the environment afforded by coastal and marine places of significance
Clean waters (CW)		Clean waters that are free of nutrient and chemical pollution, marine debris and pathogens
*Biodiversity (BD)	Habitats (HAB)	The existence value of biodiversity measured through the conservation status of habitats
	*Species (SPP)	The existence value of biodiversity measured through the conservation status of marine-associated species

Map of Ocean Health Index (OHI) per FAO high seas region.



Full results of Ocean Health Index (OHI) scores and component goal scores for each high seas region. Only three sub-goals were assessed for the high seas; the goal scores are thus determined solely by the sub-goals.

High Seas Region	Index	Food Provision (Fisheries)	Sense of Place (Iconic Species)	Biodiversity (Species)
All high seas	67	45	75	80
Pacific, Northwest	53	6	71	81
Arctic Sea	54		41	66
Indian Ocean, Eastern Indian Ocean, Eastern	55 55	8 8	78 78	80 80
Atlantic, Western- Central	58	11	81	83
Atlantic, Southeast	63	34	77	80
Pacific, Southwest	65	43	75	79
Pacific, Western Central	65	30	85	82
Pacific, Eastern Central	67	47	74	79
Atlantic, Northeast	67	61	61	81
Pacific, Northeast	68	48	71	84
Atlantic, Southwest	68	45	79	80
Atlantic, Northwest	68	63	63	79
Pacific, Southeast	76	74	74	79
Atlantic, Eastern Central	79	81	74	83
Indian Ocean, Western	79	80	76	81
All EEZs	67	59	60	83

Governance of the open ocean

Recent high-level meetings and reports have concluded that poor governance is a root cause of the unsustainability of ecosystem services from the global ocean. Current thinking about governance suggests that addressing this will require much more than the conventional historical focus on regulatory processes and enforcement. The recognition that governance is much broader than this and encompasses the private sector, civil society and resource users of all kinds has led to increased attention to the institutional arrangements and structures within which governance processes play out.

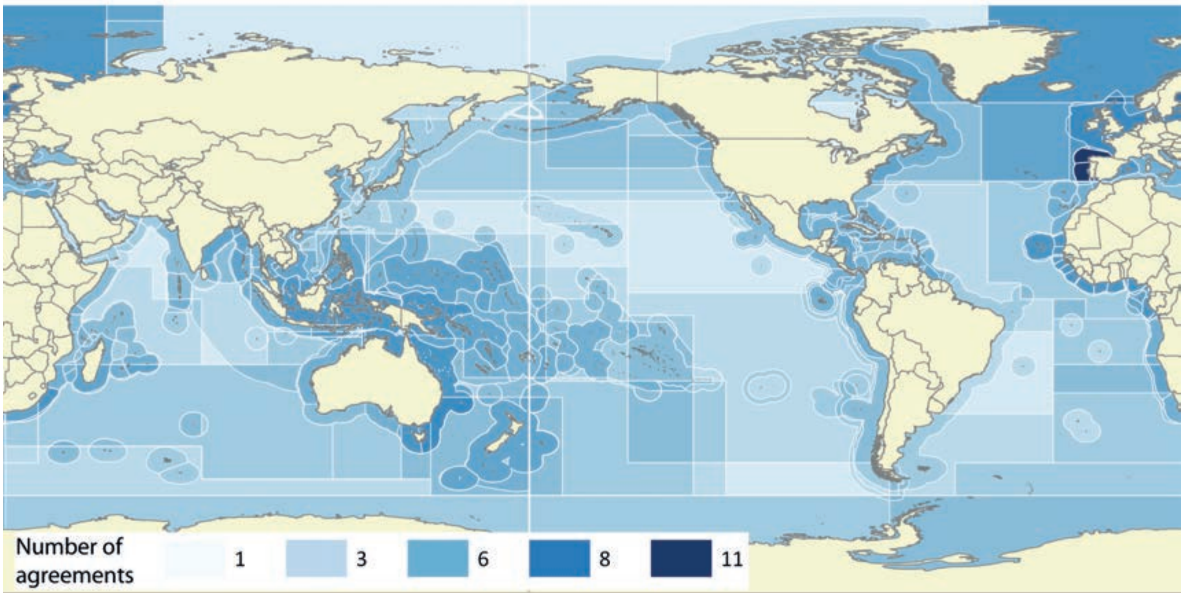
Assessing governance architecture

In this assessment, more than 100 international agreements were considered, comprising the global ocean governance architecture for the key issues in areas beyond national jurisdiction:

- fisheries
- pollution
- biodiversity
- climate change

It also examined the extent to which provision exists for practices that reflect 'good governance' in the policy processes associated with individual agreements.

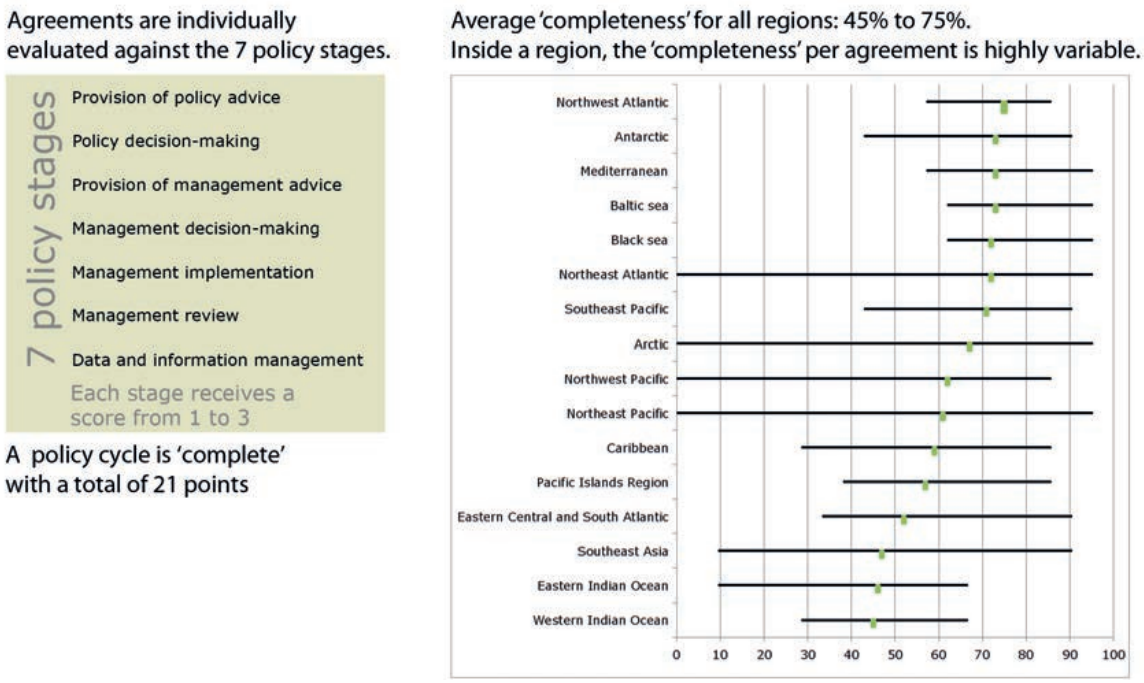
There are over 100 agreements for ocean governance covering areas beyond national jurisdiction.



Global governance architecture is fragmented, poorly integrated, and has significant gaps. There is clearly considerable room for improvement in integration at the global and regional levels. There are also significant gaps in coverage of issues, especially biodiversity. The governance assessment provides indications of where interventions are needed, and proposes an overall structure to make ocean governance architecture more approachable.

The policy processes associated with the 100 plus agreements for areas beyond national jurisdiction reveals weaknesses at several policy cycle stages, particularly decision-making and implementation. The decisions made under the processes for agreements are often only suggestions which countries are not obliged to implement. There are seldom repercussions for non-compliance.

Assessment of completeness of the policy cycle in the agreements covering areas beyond national jurisdiction (ABNJ) in regional clusters.



Risk and ocean governance

Global governance scales are needed to solve the majority of local risk posed by ocean ecosystems degradation

In order to ask the question "where are humans most at risk from transboundary water decision-making?" with respect the ocean ecosystem degradation, we analyzed *risk* as based on the *hazard* (ocean ecosystem degradation), *exposure* (population at risk, taking a human-centered view), and *vulnerability* (based on the human adaptive capacity to deal with degraded ocean ecosystem services). For this analysis, the indices used were:

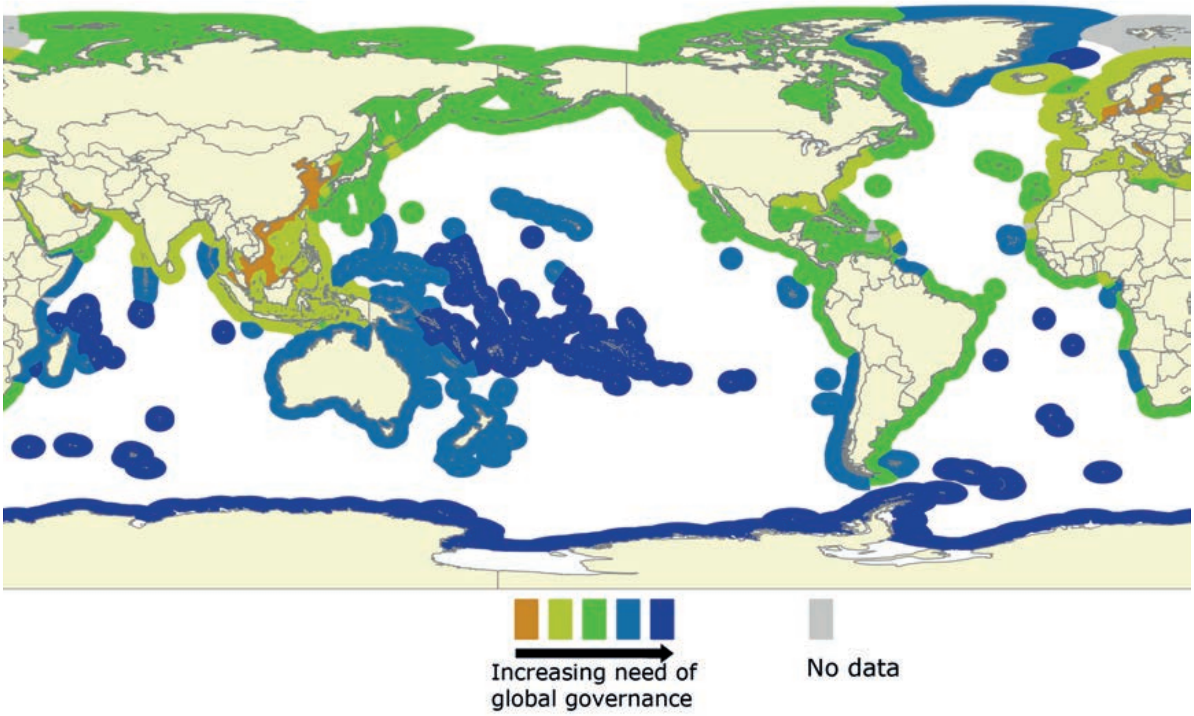
- for *hazard* the Cumulative Human Impact of 19 stressors on ocean ecosystems, in EEZ fragments as a proxy for local ocean ecosystem service degradation,
- for *exposure* the coastal population (<10 km from coast) of a country using data developed for the Sea Level Rise Risk Index, and
- for *vulnerability* the Human Development Index (HDI) of a country as a proxy for adaptive capacity (high HDI considered as least vulnerable).

A Delphi exercise determined the governance scale needed to tackle each of the stressors. For example, the ocean ecosystem stress posed by artisanal fishing, where the fishers rarely cross national boundaries, can be largely mitigated through national and local governance action. On the other hand, increased climate change as a stress on ocean ecosystems requires global governance solutions as a framework for regional and national action to be effective.

Environmental stressors needing global scale governance solutions dominate almost everywhere on the planet over those that can be dealt with primarily nationally. The portion of cumulative human impact needing global governance solutions is higher than the impact needing regional and national governance responses, for almost all countries of the world. This is especially true for EEZ fragments with low locally-driven stressors, like Antarctica and small oceanic islands.

No area of the world ocean under national jurisdiction can avoid a focus on the global governance of the oceans, as the impacts of ocean ecosystem degradation are eminently global in nature, and need coordinated global governance action to mitigate.

Map showing the ratio of risk in each EEZ fragment (defined by national coast or island) posed by human stressors on ocean ecosystems that can be managed through local governance to those that must be managed by transboundary global governance solutions to be effective. Indian and Pacific islands are particularly dependent on global governance solutions to mitigate local risk and can make relatively little difference acting only locally on stressors. Nearly all countries have a strong dependence on global governance to mitigate local risk.



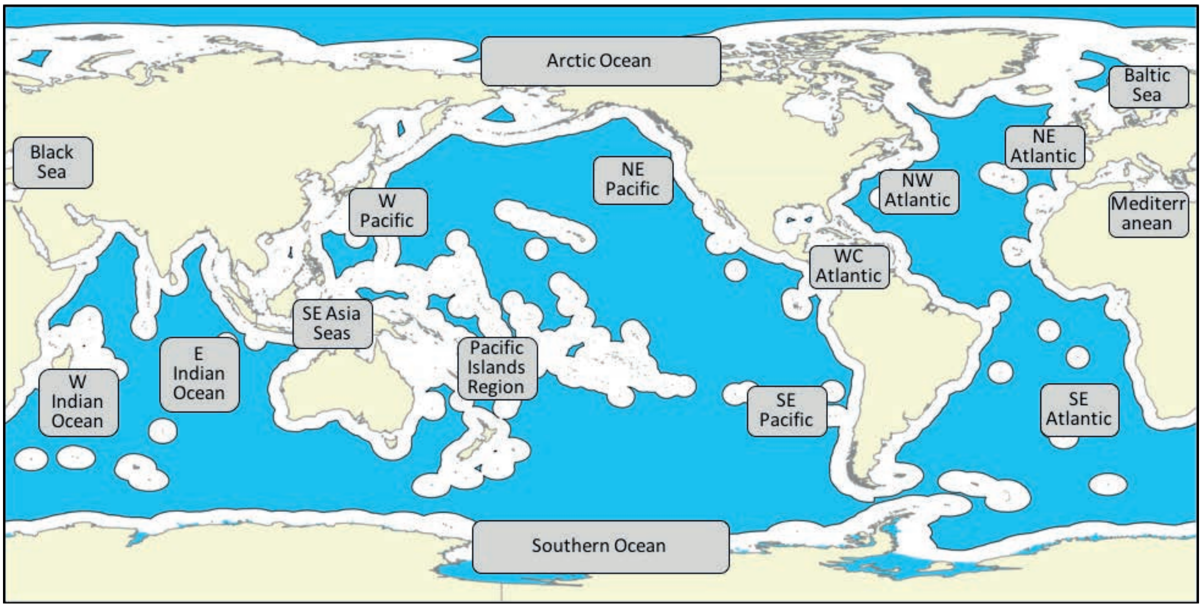
Potential role of regional clusters

Despite their current deficiencies, regional clusters could have a potentially important role in implementing EBM in their respective regions, including ABNJ if their mandates are extended, and should be the focus of initiatives to build and strengthen them. This view is supported by Rochette et al. (2014) and consistent with strategy 6 of the UNEP Regional Seas Strategic Directions 2013-2016 (UNEP 2014). The regional clusters would complement the desired 'global-to-regional, issue-based networks'. To pursue this, further work needs to be done on assessing their role and developing approaches and programs to strengthen them.

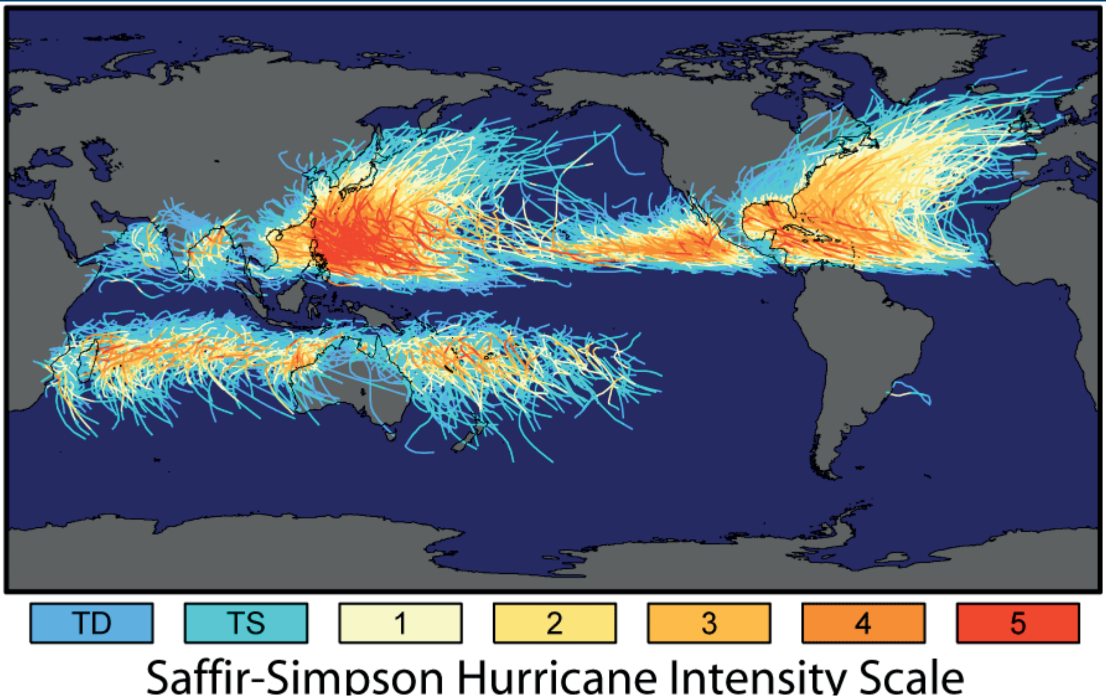
Strengthening regional clusters of agreements, particularly so that they can undertake EBM in offshore waters, including ABNJ, is seen as a critical component of strengthening ABNJ

governance. This will include promotion of integration mechanisms, expansion of mandates to include biodiversity conservation in ABNJ, improvement of interplay among arrangements within clusters, as well as building new linkages with regional multipurpose organisations to increase political understanding of and support for ocean governance. Clearly this will also strengthen governance in AWNJ.

Areas Beyond National Jurisdiction (ABNJ) are blue. The white areas depict exclusive economic zones (EEZs) (or 'areas within national jurisdiction').



Tracks of all known tropical storms from 1851 to 2006, revealing areas vulnerable to strong storms. These include regions in the Western Pacific near the Philippines and those in the Caribbean and the Gulf of Mexico. Continuing research may show how these patterns change in a warming climate (NASA Earth Observatory).



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The water systems of the world – aquifers, lakes, rivers, large marine ecosystems, and open ocean- sustain the biosphere and underpin the socioeconomic wellbeing of the world's population. Many of these systems are shared by two or more nations. These transboundary waters, stretching over 71% of the planet's surface, in addition to the subsurface aquifers, comprise humanity's water heritage.

Recognizing the value of transboundary water systems and the reality that many of them continue to be degraded and managed in fragmented ways, the Global Environment Facility Transboundary Waters Assessment Programme (GEF TWAP) was developed. The Programme aims to provide a baseline assessment to identify and evaluate changes in these water systems caused by human activi es and natural processes, and the consequences these may have on dependent human populations. The institutional partnerships forged in this assessment are envisioned to seed future transboundary assessments as well.

The final results of the GEF TWAP are presented in the following six volumes:
Volume 1 – ***Transboundary Aquifers and Groundwater Systems of Small Island Developing States: Status and Trends***
Volume 2 – ***Transboundary Lakes and Reservoirs: Status and Trends***
Volume 3 – ***Transboundary River Basins: Status and Trends***
Volume 4 – ***Large Marine Ecosystems: Status and Trends***
Volume 5 – ***The Open Ocean: Status and Trends***
Volume 6 – ***Transboundary Water Systems: Crosscutting Status and Trends***

A *Summary* for Policy Makers accompanies each volume. All TWAP publications are available for download at http://www.geftwap.org

This annex – Transboundary waters: A Global Compendium, The Open Ocean: Selected Indicators, Volume 6-Annex L -- is one of 12 annexes to the Crosscutting Analysis discussed in Volume 6. The global compendium organized into 14 TWAP regions, compiles information sheets on 765 international water systems including the baseline values of quantitative indicators that were used to establish contemporary and relative risk levels at system and regional scales. On the long term, it is envisioned that these baseline information sheets continue to be updated by future assessments at multiple spatial and temporal scales to better track the changing states of transboundary waters that are essential in sustaining human wellbeing and ecosystem health.

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