Climate change and protecting the oceans: A tale of two regimes

Presented by Nilufer Oral

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Challenges for the Ocean

Ocean warming

Ocean deoxygenation

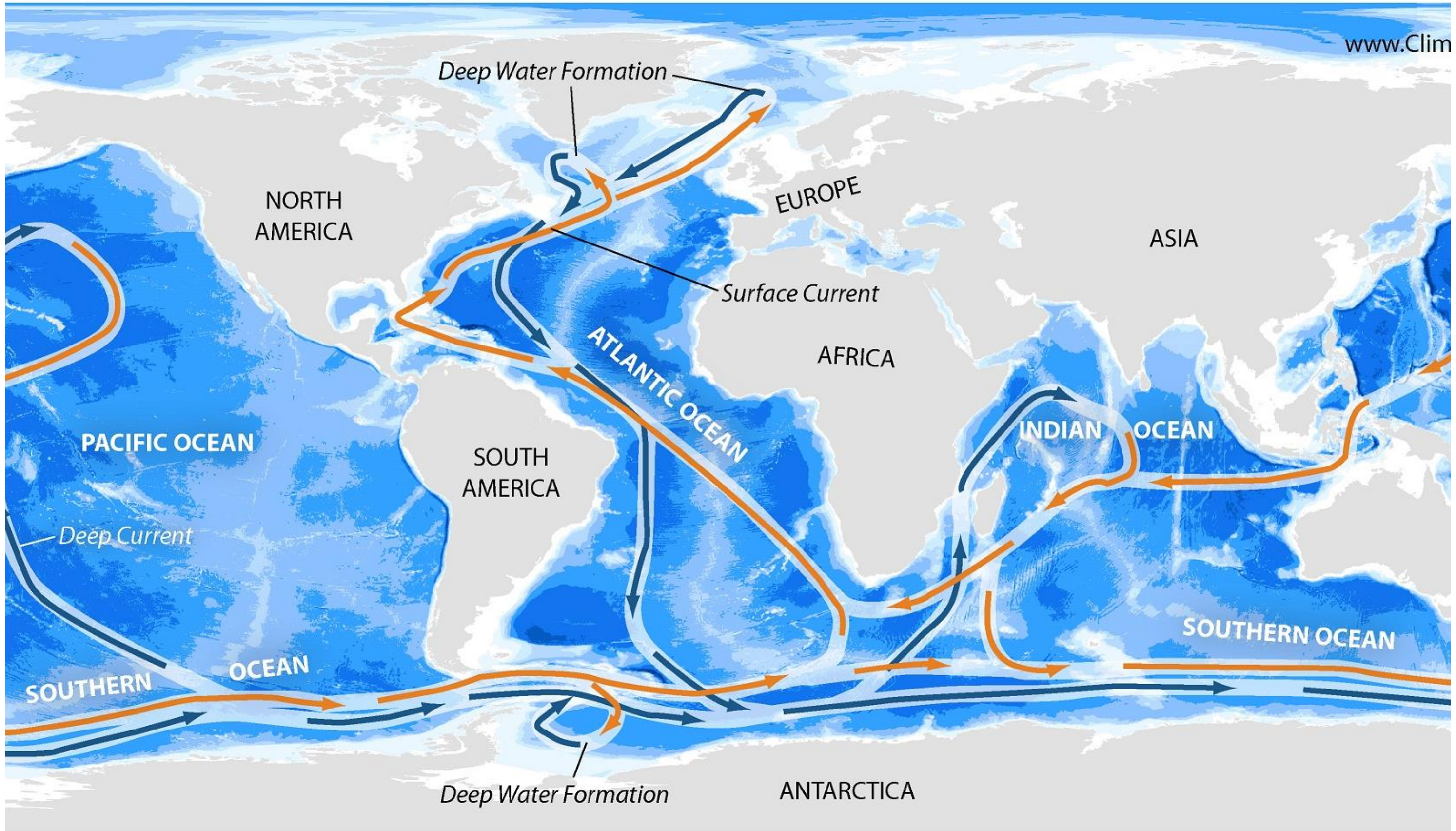
Ocean acidification

Climate Change and the Ocean

Can international law respond to the challenges?

Outline

- Part I: The science
- Part II: The law



Why is the Ocean so critical for Climate Change?

- 70% of earth's surface
- Importance of oceans to regulating the climate, weather and redistributing heat
- Oceans serve as an important sink and reservoir by absorbing and storing CO2 from the atmosphere
- Oceans have played a critical role in shielding earth from some of the more serious impacts of climate change by absorbing approximately 30 percent of emitted anthropogenic carbon dioxide
- Gulf stream (scientists say there has been a definite 10 to 15 per cent slowdown in the Gulf Stream, which brings a constant flow of warm water and mild weather to northern Europe)
- Reflective force of the oceans as a shield against solar radiation

Climate Change and the Ocean

The ocean also has a key role in the redistribution of heat from the tropics to the poles, as part of the thermohaline circulation (Meridional Oceanic Circulation, MOC) known commonly as the ‘global conveyor belt’.

The ocean's meridional overturning circulation (MOC) is a key factor in climate change

Climate Change and the Ocean

- Sea water takes up heat more than 4000 times as effectively as air and can transport and store large quantities of heat.
- As a result the ocean, due to its size and reflective (albedo) capacity, has absorbed more than 93% of the heat generated by anthropogenic global warming since 1971 (IUCN)

IPCC Fifth Report

IPCC's Fifth Assessment Report (AR5)

IPCC Fifth Report

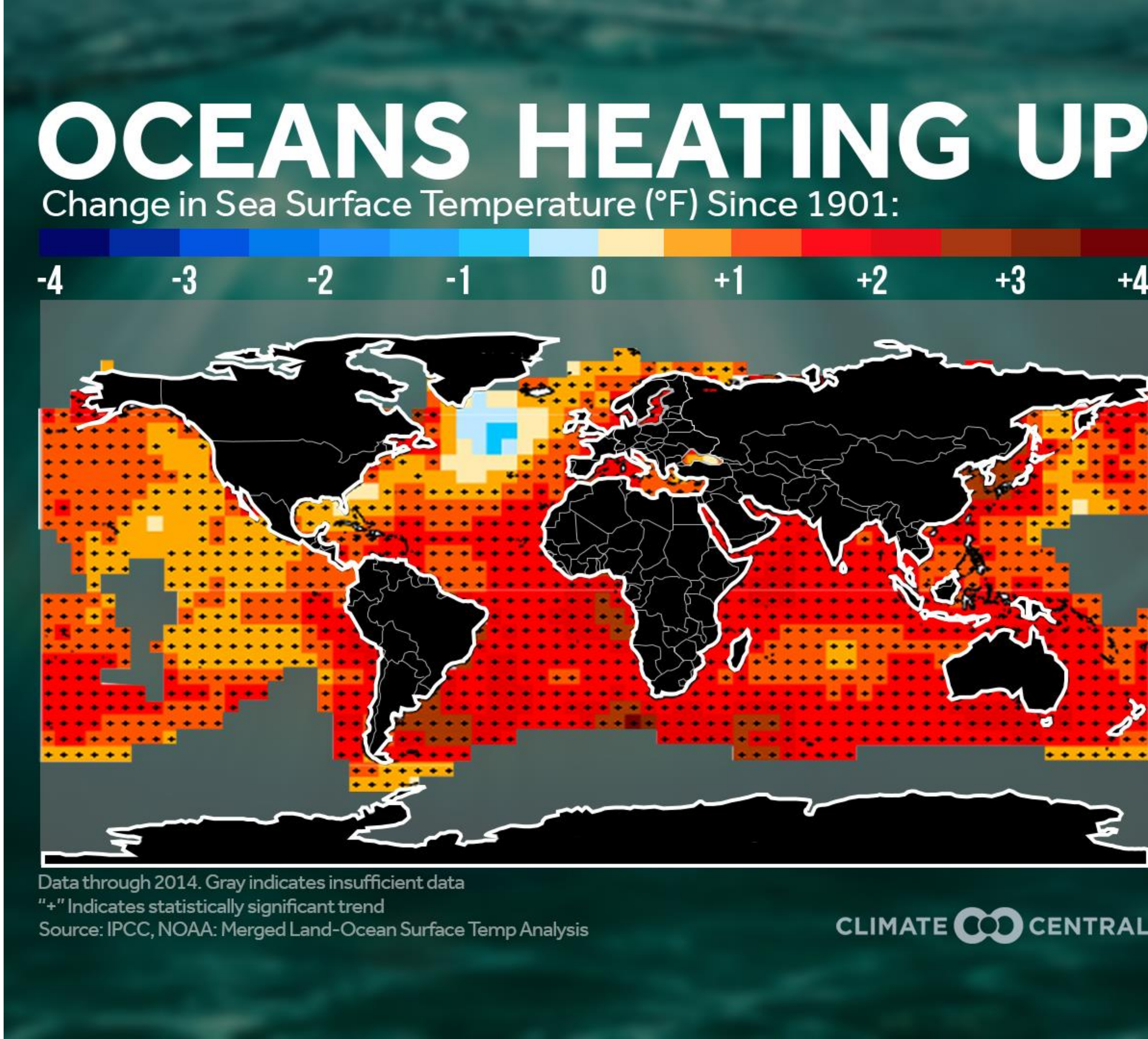
- ❖ Ocean warming dominates the increase in energy stored in the climate system, accounting for more than 90% of the energy accumulated between 1971 and 2010 (high confidence), with only about 1% stored in the atmosphere. [ocean warming is largest near the surface]
- ❖ Arctic sea-ice extent has decreased in every season and in every successive decade since 1979
- ❖ Strong evidence that ocean properties of relevance to climate have changed during the past 40 years, including temperature, salinity, sea level, carbon, pH, and oxygen.
- ❖ Since the beginning of the industrial era, oceanic uptake of CO2 has resulted in acidification of the ocean; the pH of ocean surface water has decreased by 0.1 (high confidence)

IPCC Special Report on Oceans and the Cryosphere

- At its 43rd Session (Nairobi, Kenya, 11 – 13 April 2016), the IPCC Panel decided to prepare a special report on climate change and the ocean and the cryosphere.

Ocean warming at Historic Levels

- The ocean is warmer today than at any time since record-keeping began in 1880.
- The greatest ocean warming overall is occurring in the Southern Hemisphere and is contributing to the subsurface melting of Antarctic ice shelves (IUCN)



Ocean warming: multiple impacts

- The continued warming of the oceans will have multiple impacts:
- Warming of high latitude oceans and reductions in the extent of seasonal ice (with the Arctic likely to be ice free in summer within decades),
- Increased stratification of ocean layers which reduces important mixing zones, shifting winds and currents (including changes to the thermohaline circulation)
- Falling surface water oxygen concentrations (deoxygenation)
- Impacts on the ocean ecosystem implications such as changes in productivity (decreasing in most places, increasing in some):
- range shifts and species invasions
- changes in abundance of fisheries
- increase in diseases among marine organisms, increased extinctions
- Increase in coral reef mortality.

Ocean warming: methane release

- Currently 2.5 Gt of frozen methane hydrate are stored in the sea floor at water depths of 200 – 2000 m.
- Increasing water temperature could release this source of carbon into the ocean and ultimately into the atmosphere (IUCN)
- Methane is powerful greenhouse gas

Ocean warming: El Niño and La Niña

Approximately every 3 to 7 years the surface waters of the equatorial Pacific undergo a change between exceptionally warm temperatures [as El Niño] and cold surface temperatures [La Niña] with intermediate neutral phases

Over the last 20 years there has been an intensification and significant change in the El Niño events (IUCN)

El Niño and La Niña events impacts on ecosystems in particular coral reefs

Ocean warming and coral reefs

- Tropical coral reefs represent a very small fraction of the earth's surface but provide habitat to 25% of all marine species.
- Reefs generate billions of dollars in tourism, as well as food for people in 100 countries.
- Healthy reefs also provide protection for coastal communities from storms, serving as barriers that diminish the power of waves and storm surges.

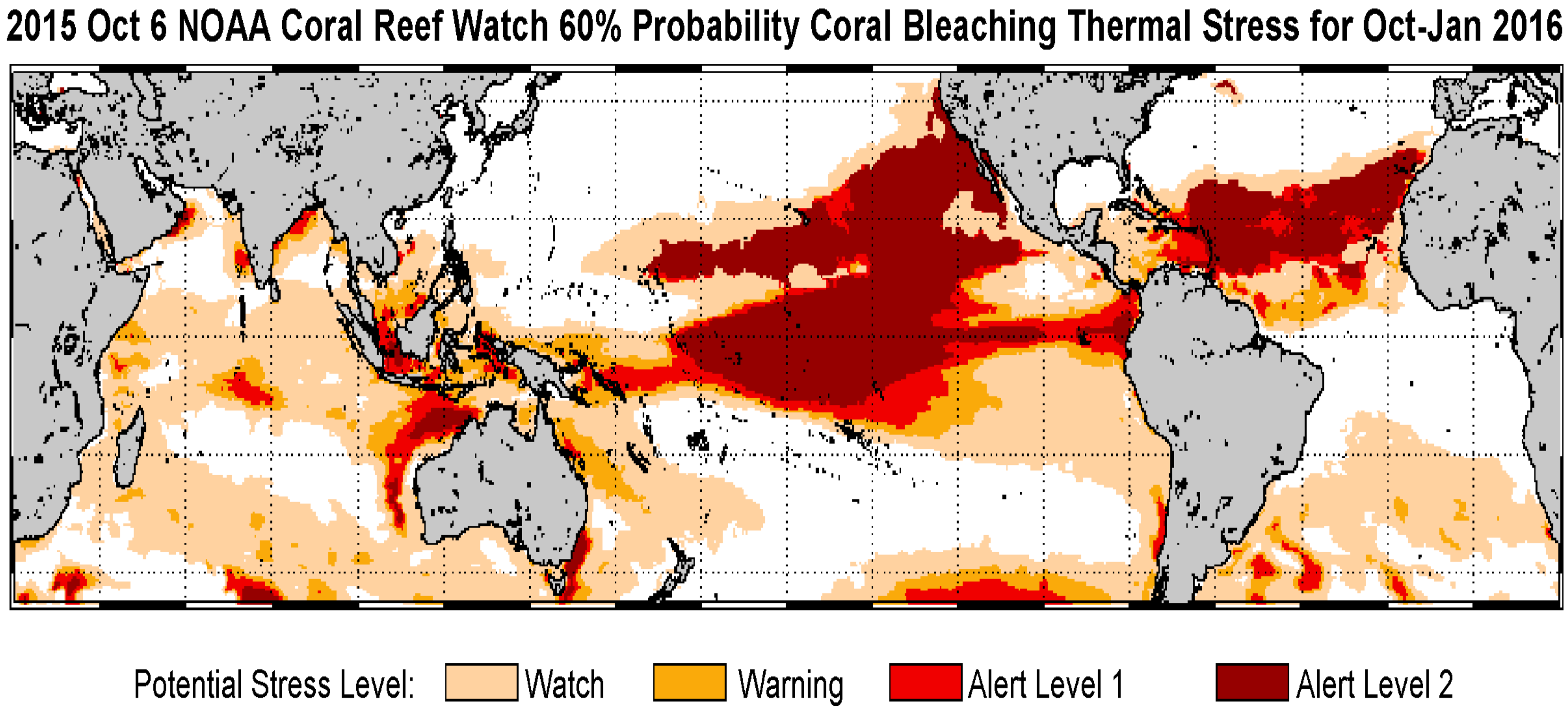
Coral Reefs

- If high CO_2 emissions continue, changes in carbonate chemistry and warming of the tropical ocean may hamper or prevent coral reef growth within decades.

Coral Bleaching

- National Oceanic and Atmospheric Department (US)
- "The coral bleaching and disease, brought on by climate change and coupled with events like the current El Niño, are the largest and most pervasive threats to coral reefs around the world."

Coral Bleaching



Ocean warming and coral reefs

- 2300 km Great Barrier Reef
- World Heritage Site
- In March 2016 an extreme heat wave resulted in the massive death of coral in the Great Barrier Reef
- **“Coral on the Great Barrier Reef was 'cooked' during 2016 marine heatwave, study finds” (NATURE, 2018)**
- **'They didn't die of starvation … They cooked'**
- "The mix of species in the future will be radically different from two years ago," according to Professor Terry Hughes from James Cook University
- **Scientists that studied the 2016 heatwave concluded that “**the 2016 bleaching event was the beginning of a long-term transformation, which has altered the Great Barrier Reef "forever".

Ocean warming and coral reefs

- 2016 Ocean heatwave killed 30 % of the Great Barrier Reef
- **Combined with a 2017 temperature spike, half of the 2 billion corals on the reef have died since 2015**
- **The species of coral that was most negatively impacted were the branching** *staghorn coral* which provides the habitat for species.
- It is being replaced with a slower growing coral
- The heat wave resulted in a transition of some 29 % of the 3,863 individual reefs that make up the Great Barrier Reef

Belize Barrier Reef

- The Belize Barrier Reef
- UNESCO World Heritage Site
- 300-kilometer (190 mi) long section of the 900-kilometer (560 mi) of the Mesoamerican Barrier Reef system
- Second largest coral reef system in the world after the Great Barrier Reef
- Study conducted in 2015 as part of the Coral Bleaching Emergency Response monitoring plan indicated that roughly 20% of sites in Belize are being affected to varying degrees, ranging from paling to full bleaching in at least a part of the coral colony

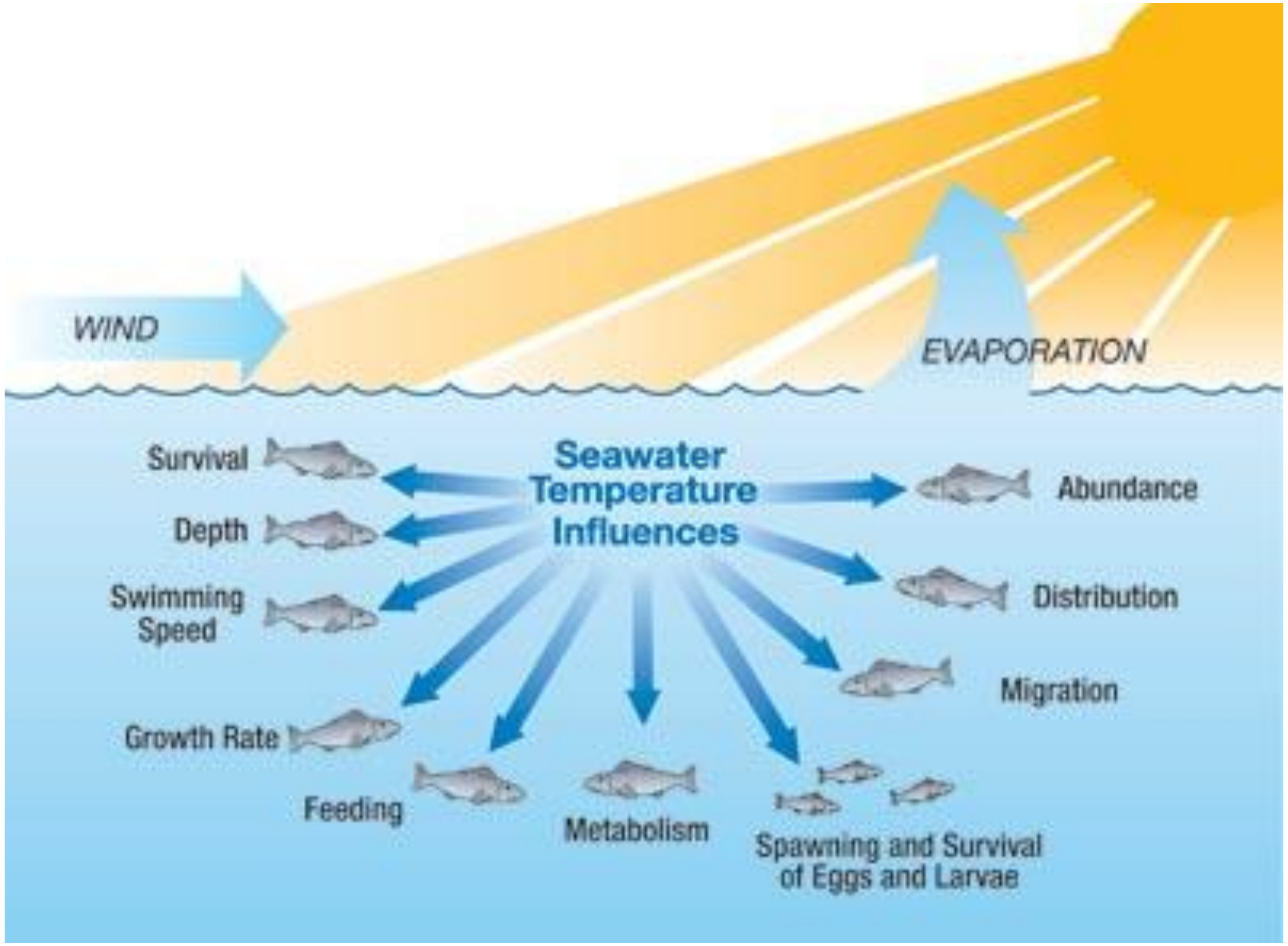
Ocean warming in the North-East Atlantic

- Warming observed in the last three decades has been particularly strong in parts of the north-east Atlantic, with the sea surface around the UK and Ireland warming at rates up to six times greater than the global average”

Fisheries and climate change

- **According to the Food and Agriculture Organization (FAO)**
- Over 500 million people depend directly and indirectly on fisheries and aquaculture for their livelihoods
- Some 3 billion people obtain their nutrition from fish and at least at least 50 % of animal protein and essential minerals for 400 million people in the poorest countries
- Impacts of climate change on the oceans will have significant impacts on fisheries and aquaculture

Ocean warming impacts on fisheries



2016 IUCN Report on ocean warming and impact on marine fisheries

IUCN Report: "Ocean warming may well turn out to be the greatest hidden challenge of our generation."

Marine fishes are sensitive to sea water temperature changes because their physiological performance is largely dependent on environmental temperature.

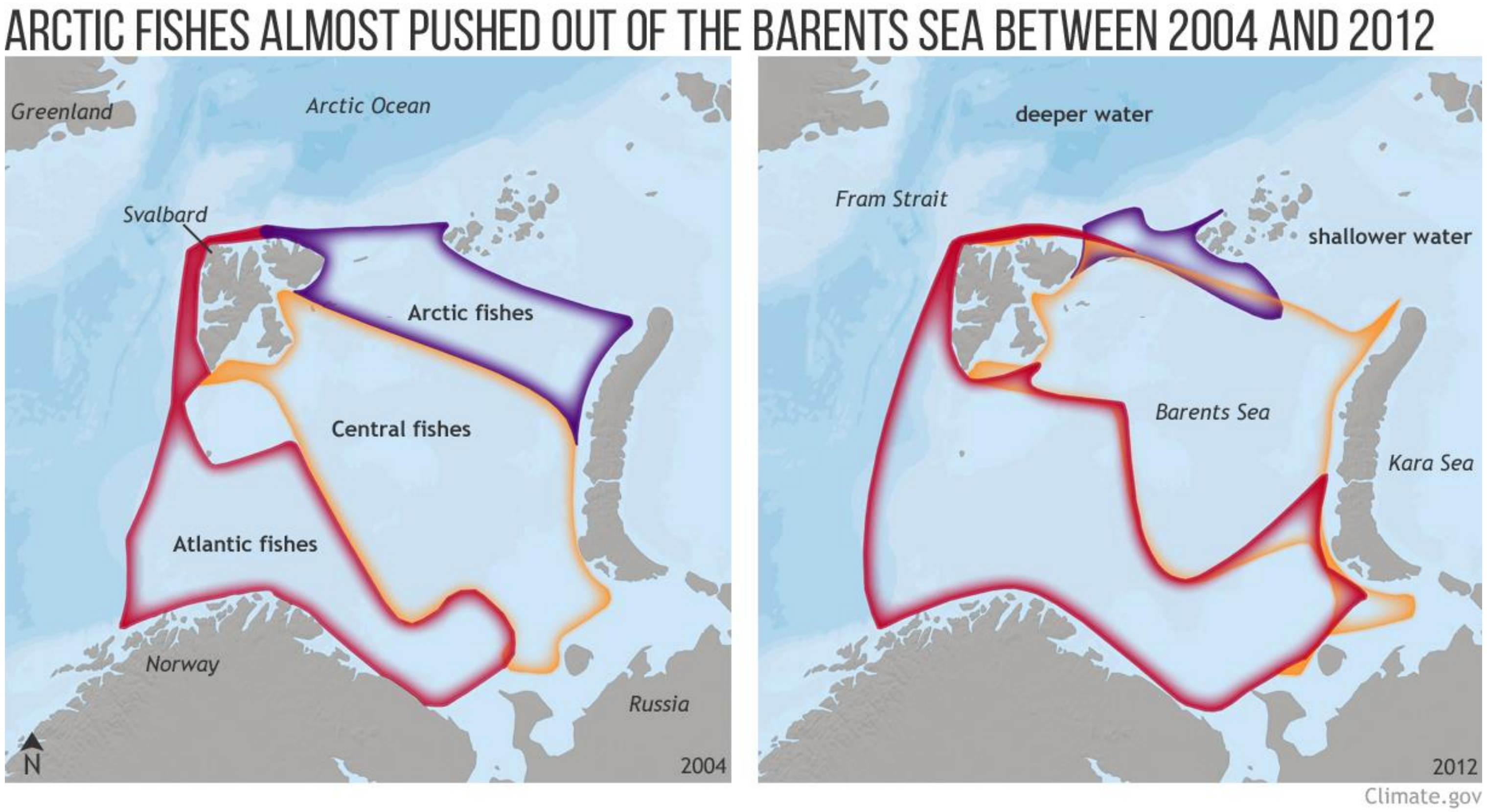
Fishes that are tropical or polar, and fish in their early life stages are generally most sensitive to ocean warming because they have narrower temperature tolerance ranges.

Fishes respond to ocean warming by modifying their distributions such that it offers habitats with suitable temperature for them to live. Observation so far suggest fishes have shifted their ranges by 10s to 100s of km as the ocean has warmed.

Altered spawning, migration and dispersal pattern

Maximum body size of fishes may decrease under ocean warming.

Marine ecosystems in the Barents warming faster than the global average



North-East Atlantic

- Amongst the 50 abundant fish species in the waters in the North-east Atlantic, 70% of the species responded to warming in the region by changing distribution and abundance between 1980 and 2008, resulting in increasing changes in species assemblages as temperature increases (IUCN)

Fisheries and climate change

Steve Simpson, a marine ecologist at the University of Exeter:

"I'm optimistic that we can have sustainable and productive fisheries, but they're not going to be the fish we used to catch,"… "It's a changing of the guard."

- "In England, sardines have replaced herring, cold water-loving cod and haddock are heading north, and bottom-dwelling sole risk being "pushed off a cliff" as suitably cool water temperatures drift away from the continental shelf. "

The Northeast Atlantic 'mackerel dispute'

- The distribution of the North-east Atlantic mackerel changed when in 2008 stocks moved northwest towards Iceland and the Faroe Islands
- Traditionally was fished by Britain, Ireland and Norway and stocks were protected by the EU quota system
- Until then not much mackerel stock in Icelandic and Faroe Island waters
- As a result of the migration stock increased significantly in Iceland and Faroe Islands waters and this led to a dispute over quotas which was eventually resolved
- Increase in the temperature of the waters is possibly the reason change in migration

Fish migration

- Thirty years ago, squid was a rarity in the North Sea. Today, boats bring back thousands of tonnes a year
- Red mullet, sardines and sea bass have also appeared with increasing frequency in North Sea fishermen's nets in recent years
- Fish species from the tropics and sub-subtropics increasingly migrating north
- A recent study revealed that 18 new species were landed in Portuguese fisheries over the past 5 years, of which 12 were tropical or subtropical

Fisheries and climate change

According to a very recent study which created a vulnerability index of 147 countries by drawing on the most recent data related to the impacts of climate change on marine fisheries:

- ❖ "The countries most vulnerable to the effects of climate change on fisheries are primarily small island states in the Pacific Ocean and Caribbean, and countries along the Western and Eastern coasts of Africa "
- ❖ "Seven out of the ten most vulnerable countries on the resulting index are Small Island Developing States, and the top quartile of the index includes countries located in Africa (17), Asia (7), North America and the Caribbean (4) and Oceania (8)"

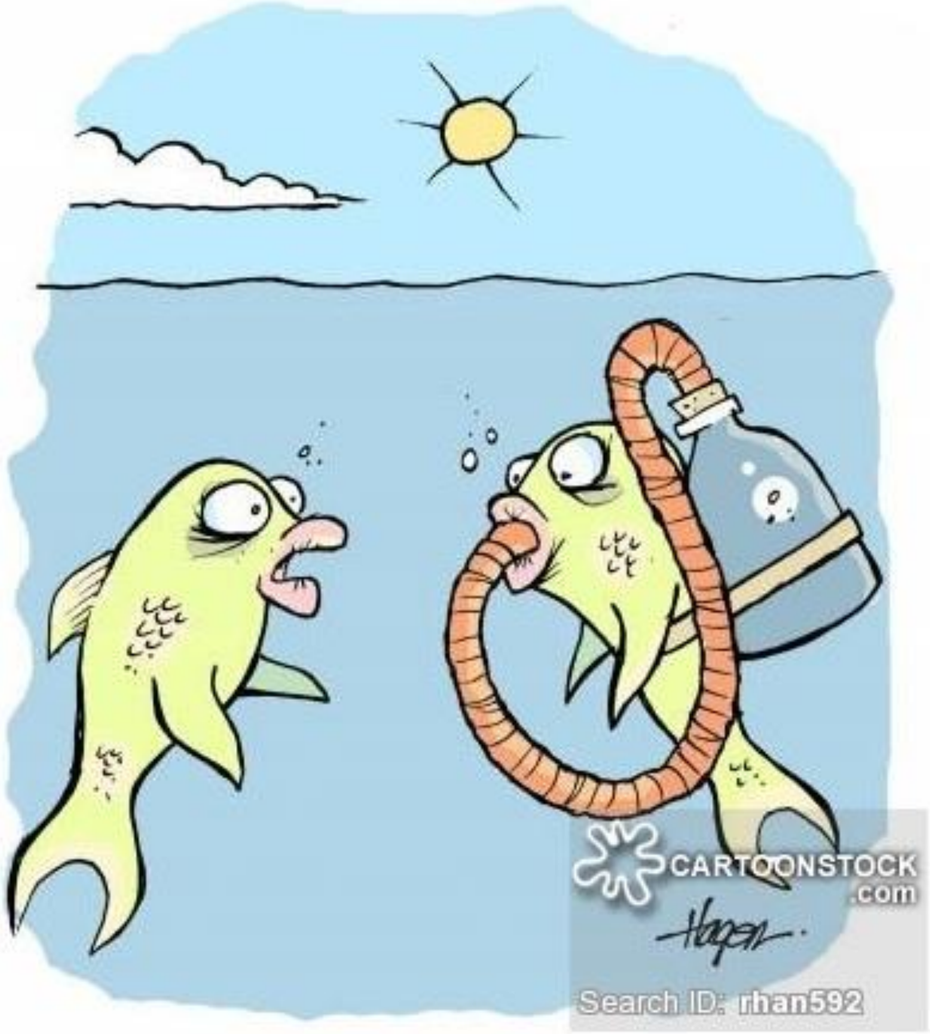
Table 1. National vulnerability to the impacts of climate change on marine fisheries.

First quartile			Second quartile			Third quartile			Fourth quartile		
Rank	Country	Vulnerability Score	Rank	Country	Vulnerability Score	Rank	Country	Vulnerability Score	Rank	Country	Vulnerability Score
1	KIRIBATI	0.999999999	38	SOMALIA	0.527489935	75	CONGO, DEM. REP.	0.426384127	112	COLOMBIA	0.295724865
2	MICRONESIA, FED. STS.	0.909266359	39	LEBANON	0.526767923	76	NICARAGUA	0.42159378	113	MALTA	0.295083491
3	SOLOMON ISLANDS	0.901230309	40	GUINEA	0.521582999	77	GUATEMALA	0.416361127	114	CAMBODIA	0.293324132
4	MALDIVES	0.867723508	41	KENYA	0.518308334	78	CUBA	0.413576655	115	KOREA, DEM. REP.	0.285808758
5	VANUATU	0.818550262	42	JORDAN	0.517966676	79	GREECE	0.413243596	116	NORWAY	0.28470084
6	SAMOA	0.810912605	43	VIETNAM	0.514346424	80	BRAZIL	0.412039257	117	CROATIA	0.282781684
7	MOZAMBIQUE	0.809247649	44	VENEZUELA, RB	0.513516643	81	EQUATORIAL GUINEA	0.408156022	118	PANAMA	0.276858295
8	CHINA	0.765473303	45	DOMINICA	0.510738028	82	SAUDI ARABIA	0.403629959	119	LITHUANIA	0.27658499
9	SIERRA LEONE	0.752615175	46	GUYANA	0.506518939	83	MOROCCO	0.400028173	120	GEORGIA	0.275699519
10	TUVALU	0.717797193	47	HONDURAS	0.501765408	84	MAURITIUS	0.398363489	121	ISRAEL	0.274817835
11	HAITI	0.699963225	48	RUSSIAN FEDERATION	0.501432395	85	ECUADOR	0.396644315	122	TURKEY	0.263301033
12	BENIN	0.688742195	49	GRENADA	0.500578354	86	BARBADOS	0.39549722	123	ALBANIA	0.261815531
13	SÃO TOMÉ AND PRINCIPE	0.675062392	50	TANZANIA	0.497444379	87	TRINIDAD AND TOBAGO	0.394045416	124	ARUBA	0.257629784
14	COMOROS	0.674417081	51	TOGO	0.496878553	88	PHILIPPINES	0.393650591	125	ITALY	0.255898034
15	NIGERIA	0.647307005	52	ANTIGUA AND BARBUDA	0.493384448	89	ST. LUCIA	0.393483814	126	FINLAND	0.255118645
16	GHANA	0.635472868	53	ERITREA	0.491403911	90	CYPRUS	0.377404848	127	BULGARIA	0.252121525
17	CAMEROON	0.629894742	54	CANADA	0.490642638	91	ALGERIA	0.372478186	128	GERMANY	0.242783003
18	BANGLADESH	0.627542039	55	SYRIAN ARAB REPUBLIC	0.487092341	92	IRAN, ISLAMIC REP.	0.368042494	129	KOREA, REP.	0.240988697
19	MADAGASCAR	0.614579906	56	BAHRAIN	0.483456871	93	PAPUA NEW GUINEA	0.367819471	130	SOUTH AFRICA	0.238938298
20	TONGA	0.611863419	57	ST. VINCENT AND THE GRENADINES	0.478559473	94	ROMANIA	0.365042589	131	POLAND	0.235972868
21	BELIZE	0.607443847	58	DOMINICAN REPUBLIC	0.478365168	95	QATAR	0.364826164	132	SLOVENIA	0.222194887
22	CÔTE D'IVOIRE	0.604657435	59	LIBYA	0.47780711	96	SINGAPORE	0.357804744	133	AUSTRALIA	0.220030046
23	SENEGAL	0.60286265	60	PAKISTAN	0.475455416	97	KUWAIT	0.351118519	134	DENMARK	0.216633221
24	GUINEA-BISSAU	0.602297241	61	CAPE VERDE	0.466089281	98	TUNISIA	0.348092428	135	BELGIUM	0.214749952
25	YEMEN, REP.	0.600418482	62	BAHAMAS, THE	0.464906157	99	MONTENEGRO	0.345855903	136	SPAIN	0.206117683
26	INDONESIA	0.594090877	63	MAURITANIA	0.456020801	100	FRANCE	0.345555062	137	JAPAN	0.203742323
27	FIJI	0.589598212	64	GABON	0.454549991	101	BRUNEI DARUSSALAM	0.344607474	138	NETHERLANDS	0.176120438
28	SEYCHELLES	0.585155228	65	DJIBOUTI	0.451695056	102	EGYPT, ARAB REP.	0.344532488	139	ARGENTINA	0.167003997
29	INDIA	0.582425245	66	LIBERIA	0.451286962	103	COSTA RICA	0.328211161	140	SWEDEN	0.16346815
30	ST. KITTS AND NEVIS	0.564704777	67	UNITED ARAB EMIRATES	0.448962558	104	ESTONIA	0.32544234	141	URUGUAY	0.15826322
31	SUDAN	0.561655443	68	MYANMAR	0.446662532	105	UKRAINE	0.323169487	142	UNITED STATES	0.15728165
32	GAMBIA, THE	0.55890093	69	MACAO SAR, CHINA	0.444714953	106	MALAYSIA	0.322866129	143	NAMIBIA	0.156395105
33	TIMOR-LESTE	0.553250138	70	CONGO, REP.	0.444645336	107	PERU	0.322511633	144	ICELAND	0.151805576
34	JAMAICA	0.546889343	71	EL SALVADOR	0.439020018	108	PORTUGAL	0.311161852	145	UNITED KINGDOM	0.12728723
35	SRI LANKA	0.528850589	72	SURINAME	0.431840825	109	HONG KONG SAR, CHINA	0.306846496	146	CHILE	0.118632105
36	ANGOLA	0.528329802	73	THAILAND	0.429072042	110	LATVIA	0.302593139	147	IRELAND	0.102390556
37	KIRIBATI	0.605730263	74	OMAN	0.493023399	111	MEXICO	0.340467051			

https://doi.org/10.1371/journal.pone.0179632.t001

Blasiak R, Spijkers J, Tokunaga K, Pittman J, Yagi N, et al. (2017) Climate change and marine fisheries: Least developed countries top global index of vulnerability. PLOS ONE 12(6): e0179632. https://doi.org/10.1371/journal.pone.0179632
http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0179632

PLOS | ONE



NOW REMEMBER, YOU HAVE ENOUGH WATER FOR HALF AN HOUR, THEN YOU'LL HAVE TO COME DOWN.

Ocean Deoxygenation

- Warm water hold less dissolved oxygen than cool water, and it also tends to divide into layers that don’t readily mix.
- According to a recent study of the ocean covering the period 1958 to 2015 results showed the ocean has been losing oxygen since the mid-1980s. The reason may be because rising temperatures have impeded circulation
- IPCC 5th Assessment Report predicts that deoxygenation will decrease by 3-6% during the 21st century in response to surface warming.

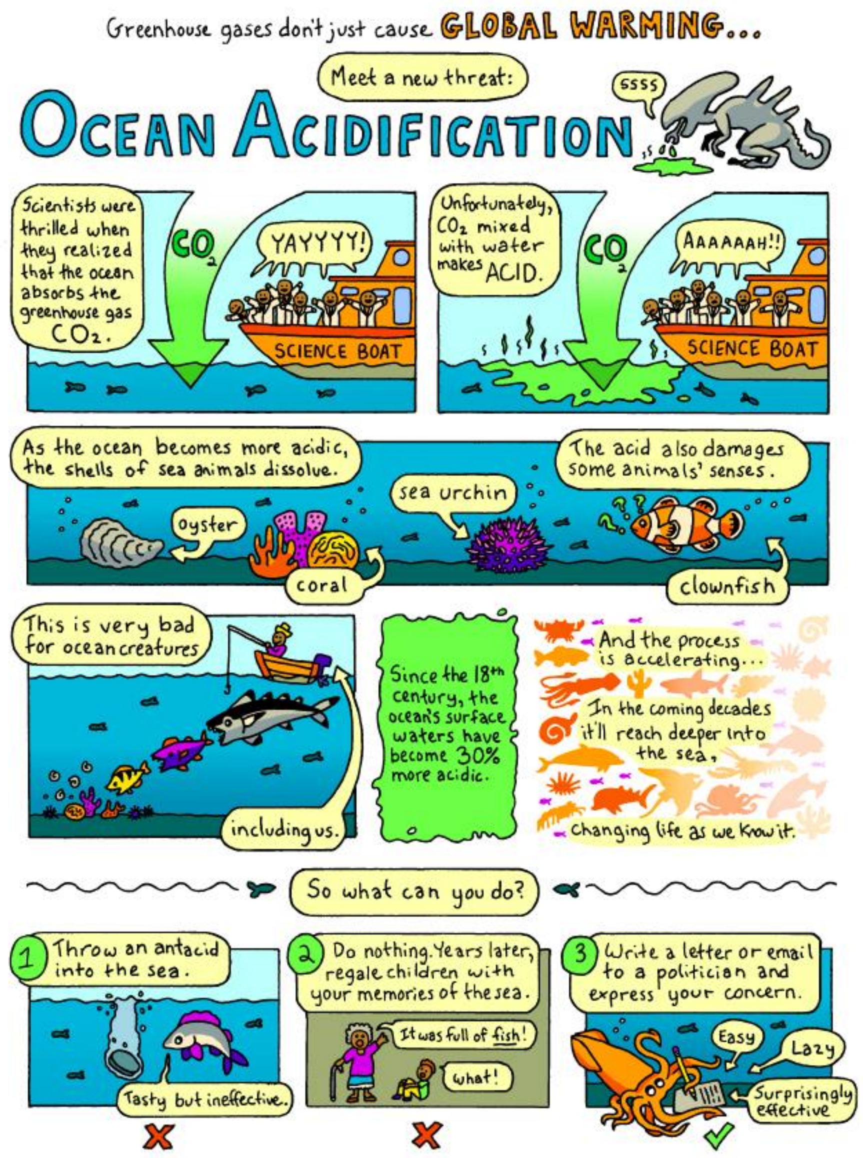
Deoxygenation

Decrease in oxygen means loss of habitats

Paradox: warmer waters also increase animals' metabolic rates, forcing them to use more oxygen to breathe and this adds to deoxygenation of the oceans

Predicted climate and oxygen conditions will create a poleward migration as equatorward waters become too low in oxygen to support their energy needs.

Eventually, the more-poleward waters will have reduced oxygen levels."


Greenhouse gases don't just cause GLOBAL WARMING...
Meet a new threat:
OCEAN ACIDIFICATION
ssss
Scientists were thrilled when they realized that the ocean absorbs the greenhouse gas CO_2.
CO_2
YAYYYY!
SCIENCE BOAT
Unfortunately, CO_2 mixed with water makes ACID.
CO_2
AAAAAAH!!
SCIENCE BOAT
As the ocean becomes more acidic, the shells of sea animals dissolve.
oyster
coral
sea urchin
The acid also damages some animals' senses.
clownfish
This is very bad for ocean creatures
including us.
Since the 18th century, the ocean's surface waters have become 30% more acidic.
And the process is accelerating...
In the coming decades it'll reach deeper into the sea,
changing life as we know it.
So what can you do?
1 Throw an antacid into the sea.
Tasty but ineffective.
2 Do nothing. Years later, regale children with your memories of the sea.
It was full of fish!
what!
3 Write a letter or email to a politician and express your concern.
Easy
Lazy
Surprisingly effective

Ocean Acidification

- Up to 50% of the carbon dioxide (CO_2) released by burning fossil fuels over the past 200 years has been absorbed by the world's oceans.
- Oceans are CO_2 satiated
- Absorbed CO_2 in seawater (H_2O) forms carbonic acid (H_2CO_3), lowering the water's pH level and making it more acidic.
- This has negative impact on marine life
- Marine creatures cannot build shell or skeletons out of calcium carbonate making them vulnerable.
- The decrease in available carbonate ions means that organisms, such as plankton, coral and mollusks, struggle to build or maintain their protective or supportive structures. • Destruction of coral reefs

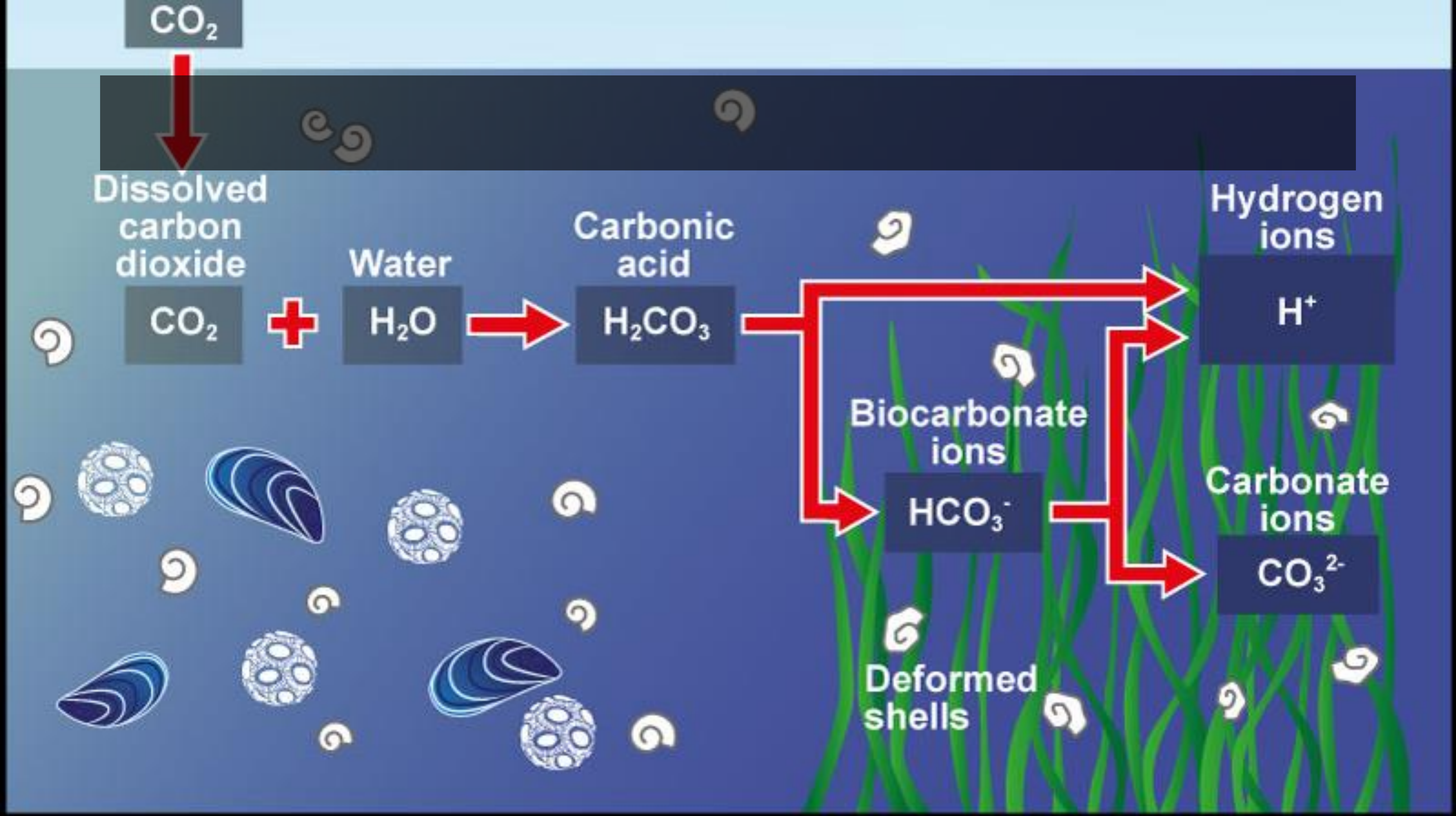
Ocean absorbs each day 24 million tonnes of CO_2

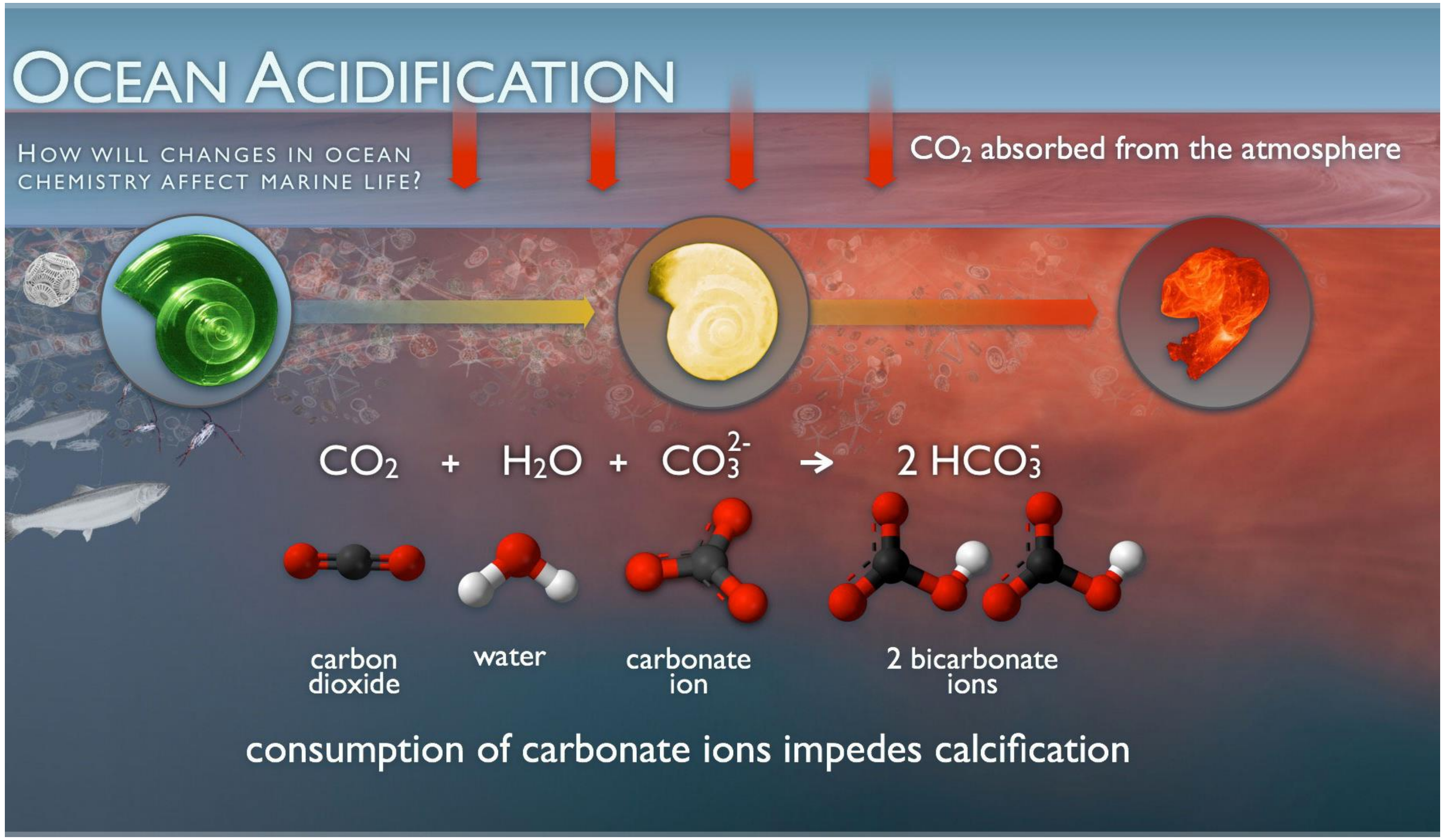
40% increase in atmospheric levels of CO_2 since the start of the industrial revolution

26% increase in ocean acidity since preindustrial levels

170% (approx)projected increase in ocean acidity by 2100 compared to preindustrial levels if high CO_2 emissions continue

10 X current rate of acidification is over 10 times faster than any time in the last 55 million years


CO_2
Dissolved carbon dioxide
CO_2
+
Water
H_2O
Carbonic acid
H_2CO_3
Hydrogen ions
H^+
Biocarbonate ions
HCO_3^-
Carbonate ions
CO_3^{2-}
Deformed shells



Ocean acidification

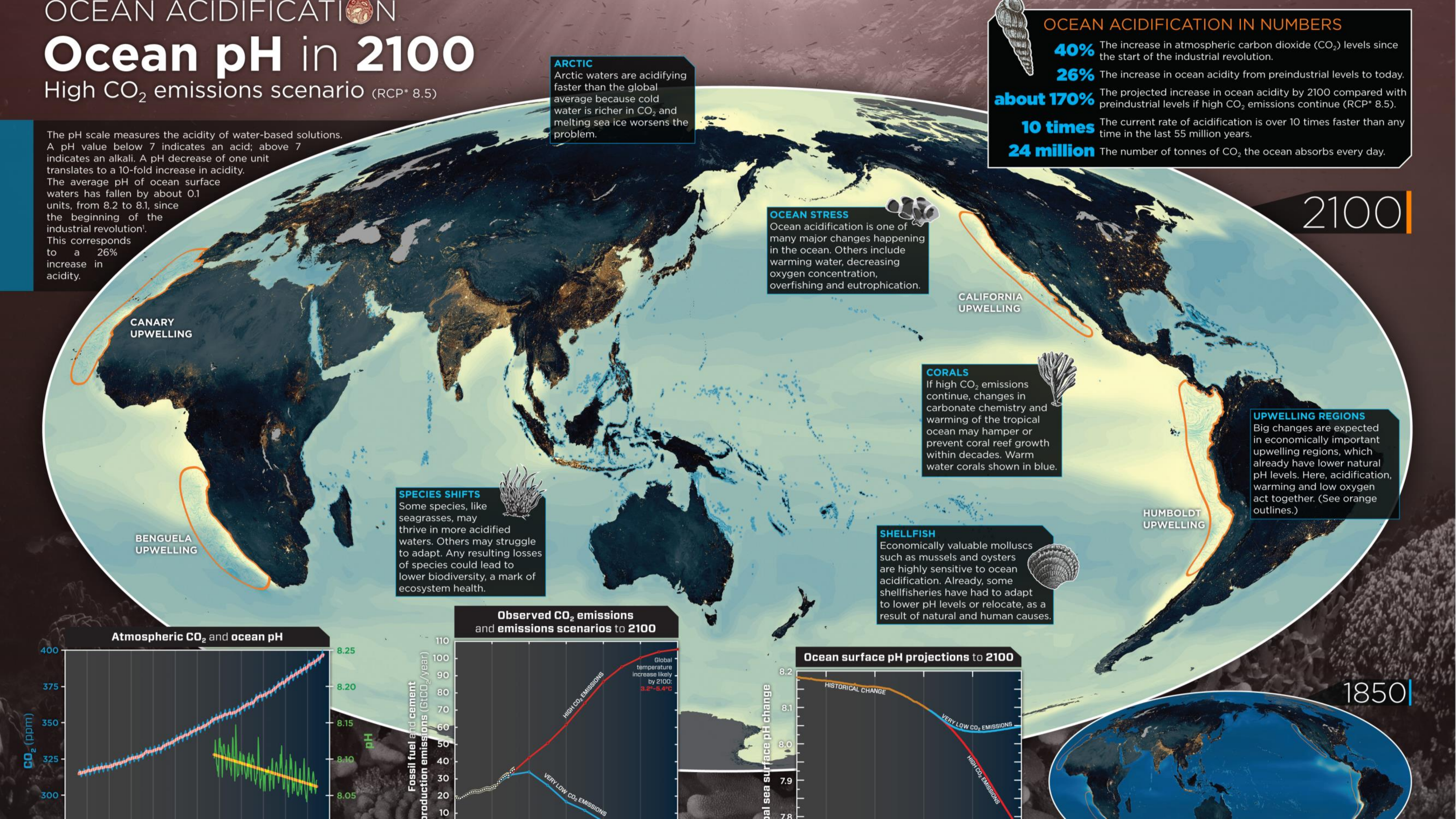
- The shells and skeletons of many marine organisms are made from either calcite or aragonite (both are forms of calcium carbonate.)
- Organisms grow shells and skeletons more easily when carbonate ions in water are abundant – "supersaturated".
- Unprotected shells and skeletons dissolve when carbonate ions in water are scarce – "undersaturated".

Ocean Acidification

National Geographic :

“For tens of millions of years, Earth's oceans have maintained a relatively stable acidity level. It's within this steady environment that the rich and varied web of life in today's seas has arisen and flourished. But research shows that this ancient balance is being undone by a recent and rapid drop in surface pH that could have devastating global consequences…”

“Over the past 300 million years, ocean pH has been slightly basic, averaging about 8.2. Today, it is around 8.1, a drop of 0.1 pH units, representing a 25-percent increase in acidity over the past two centuries.”


OCEAN ACIDIFICATION
Ocean pH in 2100
High CO_2 emissions scenario (RCP* 8.5)
The pH scale measures the acidity of water-based solutions. A pH value below 7 indicates an acid; above 7 indicates an alkali. A pH decrease of one unit translates to a 10-fold increase in acidity. The average pH of ocean surface waters has fallen by about 0.1 units, from 8.2 to 8.1, since the beginning of the industrial revolution[1]. This corresponds to a 26% increase in acidity.
ARCTIC
Arctic waters are acidifying faster than the global average because cold water is richer in CO_2 and melting sea ice worsens the problem.
OCEAN ACIDIFICATION IN NUMBERS
40% The increase in atmospheric carbon dioxide (CO_2) levels since the start of the industrial revolution.
26% The increase in ocean acidity from preindustrial levels to today.
about 170% The projected increase in ocean acidity by 2100 compared with preindustrial levels if high CO_2 emissions continue (RCP* 8.5).
10 times The current rate of acidification is over 10 times faster than any time in the last 55 million years.
24 million The number of tonnes of CO_2 the ocean absorbs every day.
2100
OCEAN STRESS
Ocean acidification is one of many major changes happening in the ocean. Others include warming water, decreasing oxygen concentration, overfishing and eutrophication.
CALIFORNIA UPWELLING
CANARY UPWELLING
CORALS
If high CO_2 emissions continue, changes in carbonate chemistry and warming of the tropical ocean may hamper or prevent coral reef growth within decades. Warm water corals shown in blue.
UPWELLING REGIONS
Big changes are expected in economically important upwelling regions, which already have lower natural pH levels. Here, acidification, warming and low oxygen act together. (See orange outlines.)
HUMBOLDT UPWELLING
SPECIES SHIFTS
Some species, like seagrasses, may thrive in more acidified waters. Others may struggle to adapt. Any resulting losses of species could lead to lower biodiversity, a mark of ecosystem health.
BENGUELA UPWELLING
SHELLFISH
Economically valuable molluscs such as mussels and oysters are highly sensitive to ocean acidification. Already, some shellfisheries have had to adapt to lower pH levels or relocate, as a result of natural and human causes.
1850
Atmospheric CO_2 and ocean pH
CO_2 (ppm)
400
375
350
325
300
pH
8.25
8.20
8.15
8.10
8.05
Observed CO_2 emissions and emissions scenarios to 2100
Fossil fuel and cement production emissions ($GtCO_2$/year)
110
100
90
80
70
60
50
40
30
20
10
HIGH CO_2 EMISSIONS
VERY LOW CO_2 EMISSIONS
Global temperature increase likely by 2100: 3.2°–5.4°C
Ocean surface pH projections to 2100
Global sea surface pH change
8.2
8.1
8.0
7.9
7.8
HISTORICAL CHANGE
VERY LOW CO_2 EMISSIONS
HIGH CO_2 EMISSIONS

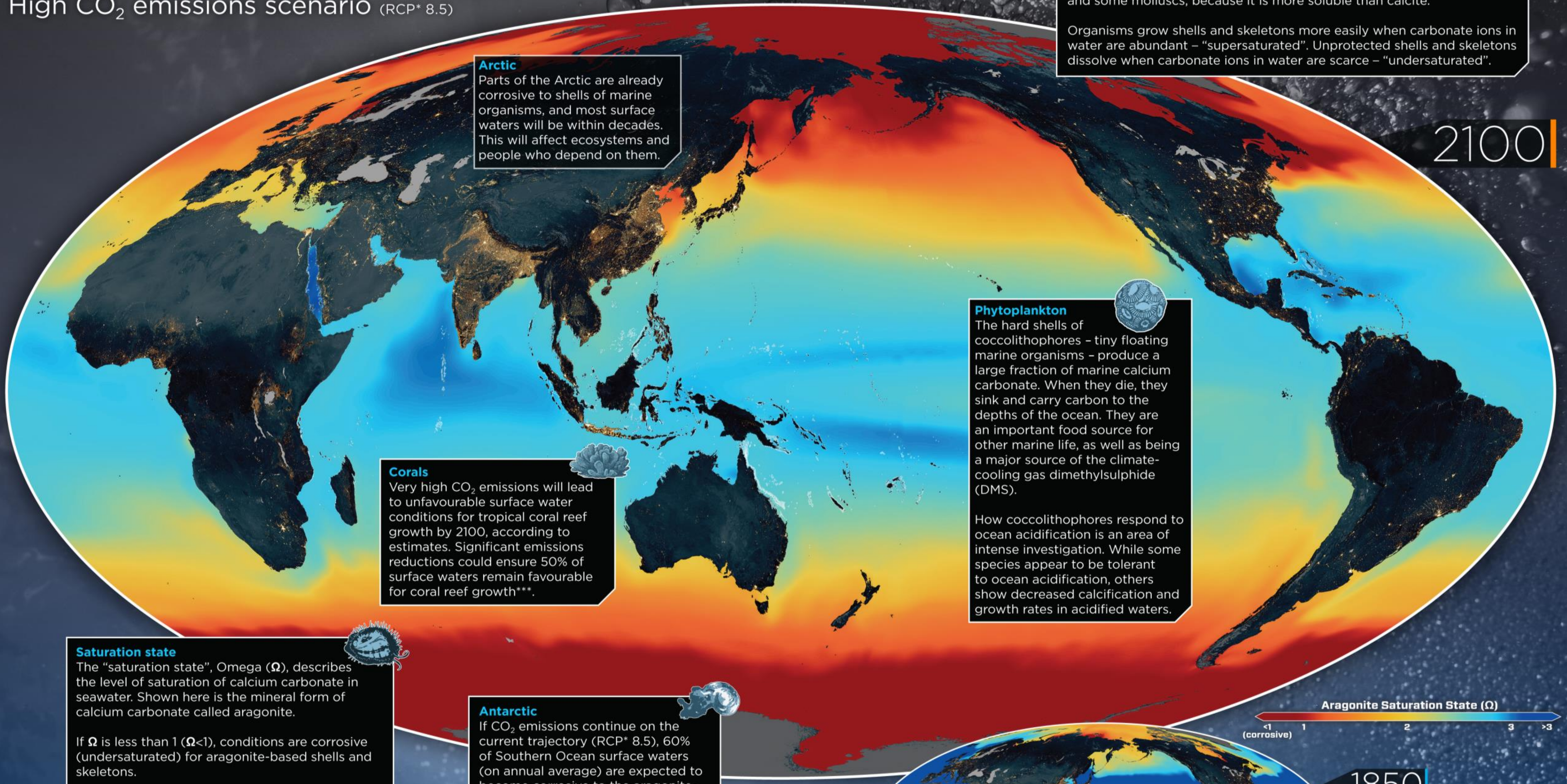
Aragonite saturation in 2100

High CO_2 emissions scenario (RCP* 8.5)

Shells and skeletons

The shells and skeletons of many marine organisms are made from either calcite or aragonite; both are forms of calcium carbonate. Scientists are particularly interested in aragonite, which is produced by many corals and some molluscs, because it is more soluble than calcite.

Organisms grow shells and skeletons more easily when carbonate ions in water are abundant – "supersaturated". Unprotected shells and skeletons dissolve when carbonate ions in water are scarce – "undersaturated".



Arctic

Parts of the Arctic are already corrosive to shells of marine organisms, and most surface waters will be within decades. This will affect ecosystems and people who depend on them.

Phytoplankton

The hard shells of coccolithophores – tiny floating marine organisms – produce a large fraction of marine calcium carbonate. When they die, they sink and carry carbon to the depths of the ocean. They are an important food source for other marine life, as well as being a major source of the climate-cooling gas dimethylsulphide (DMS).

How coccolithophores respond to ocean acidification is an area of intense investigation. While some species appear to be tolerant to ocean acidification, others show decreased calcification and growth rates in acidified waters.

Corals

Very high CO_2 emissions will lead to unfavourable surface water conditions for tropical coral reef growth by 2100, according to estimates. Significant emissions reductions could ensure 50% of surface waters remain favourable for coral reef growth***.

Saturation state

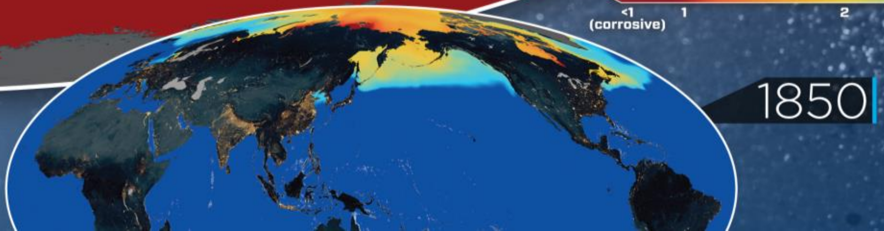
The "saturation state", Omega (**Ω**), describes the level of saturation of calcium carbonate in seawater. Shown here is the mineral form of calcium carbonate called aragonite.

If **Ω** is less than 1 (**Ω**<1), conditions are corrosive (undersaturated) for aragonite-based shells and skeletons.

When **Ω**>1, waters are supersaturated with respect to calcium carbonate and conditions are favourable for shell formation. Coral growth benefits from **Ω**≥3.

Antarctic

If CO_2 emissions continue on the current trajectory (RCP* 8.5), 60% of Southern Ocean surface waters (on annual average) are expected to become corrosive to the aragonite-shelled organisms, for example pteropods, which are part of the marine food web. Substantial emissions reductions (RCP* 2.6) could prevent most of the Southern



Commercially and ecologically important marine species vulnerable to ocean acidification

- Molluscs
- Sea urchins
- Sea cucumbers
- Starfish
- Shrimps, prawns
- Crabs and lobsters
- Herrings, sardines and anchovues
- Tuna and bonitos
- Warm and cold water coral

IUCN Report (2015)

- “The coupled effects of ocean warming and acidification are hard to predict but likely include: ocean deoxygenation, sealevel rise, a slowdown of ocean circulation and changes in the structure of marine ecosystems and ocean primary production”

Climate Change and the Ocean

Can international law respond to the challenges?

- The United Nations General Assembly has reiterated its serious concern over the current and projected adverse effects of climate change on the marine environment and marine biodiversity, including coral reefs as well as the vulnerability of the environment and the fragile ecosystems of the polar regions, emphasizing the urgency of addressing this issue
- (UN A/RES/64/71; A/RES/66/231; A/RES/71/257)

A tale of two regimes

- The Law of the Sea Convention was negotiated during a period where concerns of climate change were not known. Consequently, despite the importance the Convention gave in Part XII to protection and preservation of the marine environment, understandably it did not make reference to the adverse impacts of climate change on the ocean and the marine environment.
- By contrast, the Framework Convention on Climate Change was negotiated when information on the impacts of climate change on the oceans was not as well understood and studied.

A tale of two regimes

- Dilemma: We have on the one hand a convention that is intended to cover all matters related to the ocean, but does not expressly refer to climate change
- And on the other hand we have a convention intended to cover matters related to climate change but is very terrestrial and atmospheric in its scope with a very limited application to the ocean

Climate Change and the Oceans: Which regime?

UNFCCC

- United Nations Framework Convention on Climate Change
- Kyoto Protocol as amended
- Paris Agreement

UNCLOS

- United Nations Convention on the Law of the Sea
- 1995 United Nations Fish Stock Agreement on Straddling and Highly Migratory Fish stocks
- Possible new internationally legally binding instrument for the conservation and sustainable use of biological diversity beyond national jurisdiction (ILBI)

Climate Change and the Oceans: Which regime?

UNFCCC

- No reference to the adverse impacts of climate change on the ocean and the marine environment

UNCLOS

- Very terrestrial and atmospheric in its scope with a very limited application to the ocean.

Climate Change Regime Six Greenhouse gas

Six Greenhouse gas excluding those covered under the Montreal Protocol	Carbon dioxide (fossil fuels [57%] and deforestation) [76,7%]
	Methane (agricultural activities • energy production • waste)[14.3%]
	Nitrous oxide (mainly agricultural activities) [7.9%]
	Hydrofluorocarbons (to replace ozone-depleting substances) [1.1%]
	Perfluorocarbons (to replace ozone-depleting substances)
	Sulphur hexafluoride (used in some industrial processes and in electric equipment)

Greenhouse Gases

- **Carbon dioxide equivalent** is a measure used to compare the emissions from various greenhouse gases based upon their global warming potential (GWP)
- GWP for Co2 for over 100 years is 1
- GWP for methane over 100 years is 21
- GWP for nitrous oxide over 100 years is 310

UNFCCC

- **<u>Definition:</u>**
- Climate system: “the totality of the atmosphere, hydrosphere, biosphere and geosphere and their interactions “
- Hydrosphere includes the ocean

Article 2: Objective

- The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention:
- stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.
- Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change,
- to ensure that food production is not threatened and
- to enable economic development to proceed in a sustainable manner.

UNFCCC Regime

UNFCCC

- Article 2 (ultimate objective) indicators
- (1) stabilization of greenhouse gas concentrations in the atmosphere,
- (2) such stabilization is to be at a level that prevents dangerous anthropogenic interference with the climate system, and
- (3) looks to the temporal dimension that will allow for a natural period of adaptation for ecosystems
- (4) Ensure food production security
- (5) Ensure sustainable development

- Objective
- (1) is "atmospheric"
- How would this apply to the temperature of the oceans?
- How would this apply to pH levels for ocean acidification?
- (2) Can the marine ecosystems adapt naturally to ocean warming/deoxygenation/acidification
- (3) Fisheries? Marine food chain?

1992 UNFCCC

Place of the ocean is a sink and reservoir

- **Article 4 (d) Commitment of all Parties to :**
- "Promote sustainable management, and promote and cooperate in the **conservation and enhancement, as appropriate, of sinks and reservoirs** of all greenhouse gases not controlled by the Montreal Protocol, including biomass, forests and **oceans** as well as other terrestrial, **coastal and marine ecosystems**;"

- Oceans as "sink "(remove) or "reservoir" (store) for mitigation purposes

Kyoto Protocol and Doha amendment

Mitigation

Mitigation obligation:

- The Parties included in Annex I shall, individually or jointly, ensure that their **aggregate anthropogenic carbon dioxide equivalent emissions** of the greenhouse gases listed in Annex A do not exceed their assigned amounts (Article 3.1)
- Adopt policies to protect and enhance sinks and reservoirs of greenhouse gases not controlled by the Montreal Protocol

- The obligation encompasses all six GHG
- Kyoto Protocol is land-based (LULUCF)
- Oceans role as a CO_2 sink to be protected and enhanced
- REDD and REDD+ for forests
- Oceans? (Blue carbon initiative?)

2015 Paris Agreement

- *Preamble*
- Recognizing the importance of the conservation and enhancement, as appropriate, of sinks and reservoirs of the greenhouse gases referred to in the Convention,
- Noting the importance of ensuring the integrity of all ecosystems, including oceans, and the protection of biodiversity….

2015 Paris Agreement

Controlling increase in global average temperature

Article 2

- Long-term goal of keeping the increase in the global average temperature to **well below** 2°C above pre-industrial levels
- To aim to limit the increase to 1.5°C

How do oceans fit in?

1. Can ocean warming/ deoxygenation/ acidification balance be assessed within this degree framework?
2. Is there a corollary benchmark for the ocean? For ocean temperature? Ph levels?

2015 Paris Agreement

Peaking

Article 4

In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global **peaking of greenhouse gas emissions as soon as possible,** recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter …

How do oceans fit in?

1. Applies to all GHG
2. Can ocean warming/ deoxygenation/ acidification balance be assessed within this framework?
3. Is there a peaking limit that is linked to the ocean?

2015 Paris Agreement

“Sinks” and “Reservoirs”

- **Article 5**
- 1. Parties should take action to conserve and enhance, as appropriate, sinks and reservoirs of greenhouse gases as referred to in Article 4, paragraph 1 (d), of the Convention, including forests.

- **Indirectly includes the ocean but emphasis on forests**
- Large quantities of carbon are stored in land-based ecosystem.
- Largest source of Co2 after fossil fuels is from land use (deforestation and agriculture)
- Oceans will benefit but the problem is the linkage to atmospheric levels of GHG (article 2 of UNFCCC)

2015 Paris Agreement

“Terrestrial orientation "

- Article 5
- 2. Parties are encouraged to take action to implement and support, including through results-based payments, the existing framework as set out in related guidance and decisions already agreed under the Convention for: policy approaches and positive incentives for activities relating to reducing emissions from deforestation and forest degradation, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries; and alternative policy approaches, such as joint mitigation and adaptation approaches for the integral and sustainable management of forests, while reaffirming the importance of incentivizing, as appropriate, non-carbon benefits associated with such approaches.

- Article 5(2) is about promoting sustainable management of forests – but there is no equivalent provision or mechanism under the UNFCCC regime for the ocean

2015 Paris Agreement

Adaptation

- Article 2
- (b) **Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience** and low greenhouse gas emissions development, in a manner that does not threaten food production;

- Ocean warming /deoxygenation and adaptation?
- Ocean acidification?
- Fisheries? Coral reefs? Habitats?
- Ocean circulation?

2015 Paris Agreement

Nationally Determined Contributions

- Article 4 and NDCs
- Each Party shall prepare, communicate and maintain successive **nationally determined contributions** that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions.

- How can NDCs contribute to reducing ocean warming,deoxygenation and acidification?

2015 Paris Agreement

Adaptation planning

- Article 7(9). Adaptation planning
- **Each Party shall**, as appropriate, engage in adaptation planning processes and the implementation of actions, including the development or enhancement of relevant plans, policies and/or contributions, which may include:
- (c) The assessment of climate change impacts and vulnerability, with a view to formulating nationally determined prioritized actions, taking into account vulnerable people, places and ecosystems;

- Climate change impacts on ocean ecosystems included in this assessment?
- Should this be required?

2015 Paris Agreement

Global stocktaking

- **Article 14- Global Stocktaking**
- Every 5 years
- First will be in 2023
- Includes both mitigation and adaptation actions
- The outcome of the global stocktake shall inform Parties in updating and enhancing, in a nationally determined manner, their actions and support in accordance with the relevant provisions of this Agreement, as well as in enhancing international cooperation for climate action.

- Include the Ocean as part of the global stocktaking determination of enhanced action?
- Problem: What will be the indicator? Article 2 of UFCCC relates to atmospheric levels of GHGs

- Again, will the process remain linked to atmospheric goals and indicators without including the ocean?

United Nations Convention on the Law of the Sea

Preamble

- *Recognizing* the desirability of establishing through this Convention, with due regard for the sovereignty of all States, a legal order for the seas and oceans which will facilitate international communication, and will promote the peaceful uses of the seas and oceans, the equitable and efficient utilization of their resources, **the conservation of their living resources, and the study, protection and preservation of the marine environment,**

1982 UNCLOS

Duty to protect and preserve the marine environment

- **Article 192**
- States have the obligation to protect and preserve the marine environment.
- Applies to all areas of the oceans

- Direct obligation
- Duty includes to protect against climate change impacts?

Article 192

- **The South China Sea Arbitral Tribunal:**
- The obligation to "protect" the marine environment means protection from *future* damage
- To "preserve" means to *maintain* or *improve* the existing condition of the marine environment
- Furthermore, the Tribunal stated that these two elements included the obligation to take *active* measures and to prevent the degradation of the existing marine environment.
- How would this apply to ocean acidification?

1982 UNCLOS

“Pollution”

- 1982 UNCLOS
- Pollution (Article 1(1)(4)
- “the introduction by man, directly or indirectly, of substances or energy into the marine environment, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, .. [= Co^2]

- Is CO2 pollution?
- It fits the definition in UNCLOS and therefor would come within its scope of application.

1982 UNCLOS

Transboundary pollution

- **Article 194** Duty to adopt necessary measures to prevent, reduce and control pollution from any source, including transboundary pollution
- Duty to adopt adopt measures to prevent transboundary pollution from all sources of pollution from activities under jurisdiction or control of states (all States!)
- **Article 194 (5**) *includes duty to protect* rare or fragile ecosystems, habitat or depleted, threatened or endangered species and other forms of marine life.

- Climate change is a transboundary source of pollution
- Duty includes the protection against climate change impacts
- Duty of Parties to protect the oceans, rare and fragile ecosystems, marine living resources from deleterious impacts of climate from human activities?
- Does climate change create a new level of obligation for those species and habitats at risk from climate change impacts on the oceans?

1982 UNCLOS

Article 194 and Due diligence obligation

- International Tribunal for the Law of the Sea, the use of the language "to ensure" creates an obligation of due diligence
- Means an obligation to adopt the appropriate rules and measures, exercise vigilance in their enforcement, and also monitor the activities of private and public operators
- an obligation to deploy adequate means, to exercise best possible efforts, to do the utmost, to obtain. . ." the required result

- Question:
- Do States have a due diligence obligation under Article 194 to regulate and control activities such as carbon dioxide emitting power generators that use oil or coal, oil extraction industries, coal-mining?

1982 UNCLOS

Land-based sources

- Article 207 : Duty to protect against land-based sources of pollution
- Article 212 : Duty to adopt laws and regulations to prevent pollution of the marine environment through the atmosphere

- Does this create a duty to mitigate against land-based activities that impact the oceans?
- CO2 = pollution this would apply to atmospheric sources of climate change impacts to the oceans

Marine Living Resources

UNCLOS

- Article 61 (EEZ)
  - Focus is on exploitation and prevention of over-exploitation
  - But, measures are to be designed to maintain or restore populations of harvested species that can produce maximum sustainable yield

Comments

- What measures can be taken to restore migrating fish stocks due to ocean warming/acidification?

Marine Living Resources

1995 Fish Stocks Agreement

- Applies to and Straddling and Highly Migratory Fish Stocks
- (Fish is defined to include molluscs and crustaceans except those that are sedentary)
- Objective is to to ensure the “long-term sustainability” of straddling and HMFS
- States have a duty to adopt measures based on best scientific evidence to ensure the “long-term sustainability” of straddling and HMFS designed to maintain or restore stocks at levels capable of producing MSY
- Duty to assess “the impacts of fishing, and other human activities and environmental factors …”

- What about fish stocks that are changing their migratory patterns?
- How will RFMO’s address this issue? Recall the problem with the North-east mackerel. Do we need additional normative framework for this?

Climate change and oceans: Is there a gap in the international legal framework?

UNFCCC?

Kyoto/Doha?

Paris Agreement?

UNCLOS?

BBNJ?

UN Informal Consultative Process

What steps?

UNFCCC

- COP decision?
- Paris Agreement
  - NDCs
  - National Adaptation Priorities

- UNCLOS

- BBNJ ILBI?
- New IA under UNCLOS for climate change?
- Advisory Opinion from UNCLOS on obligations of States?
- Coral Reef Initiative and possible binding instrument?

UN-Oceans

- What role can UN-Oceans play in creating greater synergy between these two regimes ?

Conclusions

- Oceans under threat from “climate change”
- There is no clear legal regime under international law addressing climate change and the ocean
- Climate Change regime very limited in addressing oceans issues- it is terrestrial and atmospheric in its focus
- Law of the Sea Convention has the components and established clear obligations including for land-based source activities
- Can these two regimes be coordinated to fully address this critical issue?
- Can international law provide the necessary collective framework to address this pressing concern of the international community?

Thank you

Thank you