CLIMATE-HUMAN-POLICY CONNECTIONS IN DEEP-OCEAN ECOSYSTEMS

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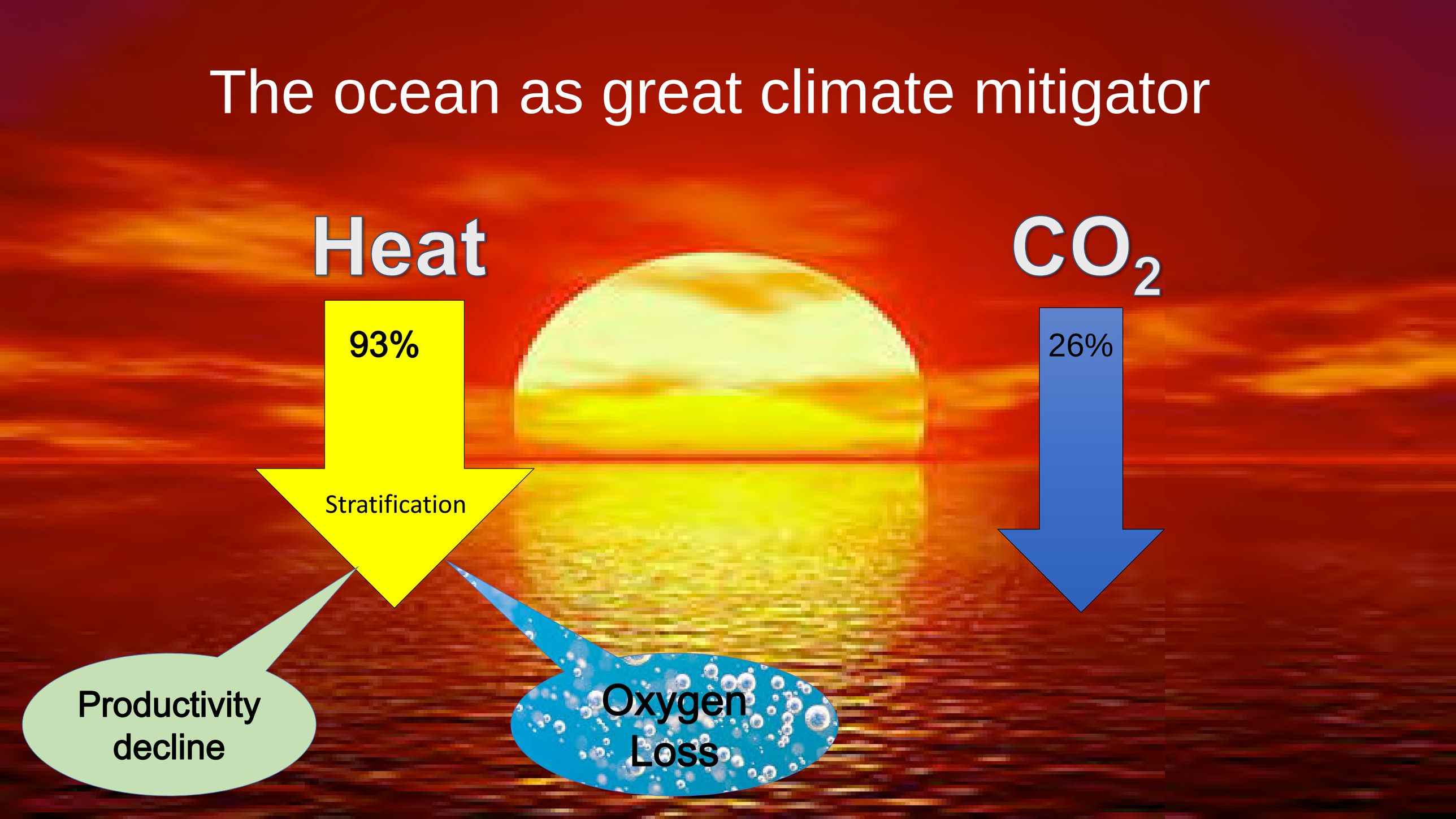
Effects of Climate Change in the World Oceans

Washington DC , June 2018

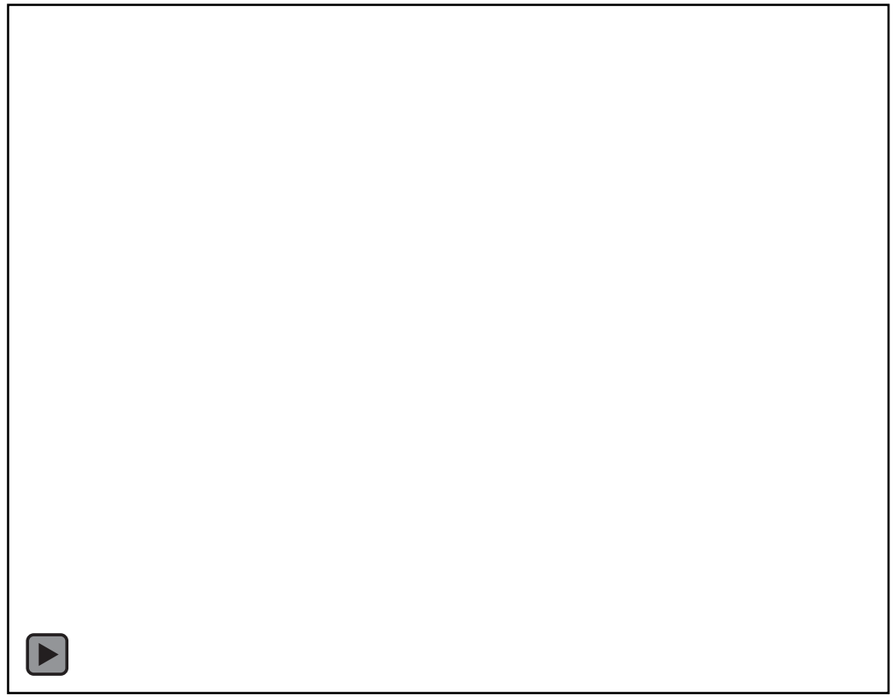
Climate-Human-Policy Connections in the Deep

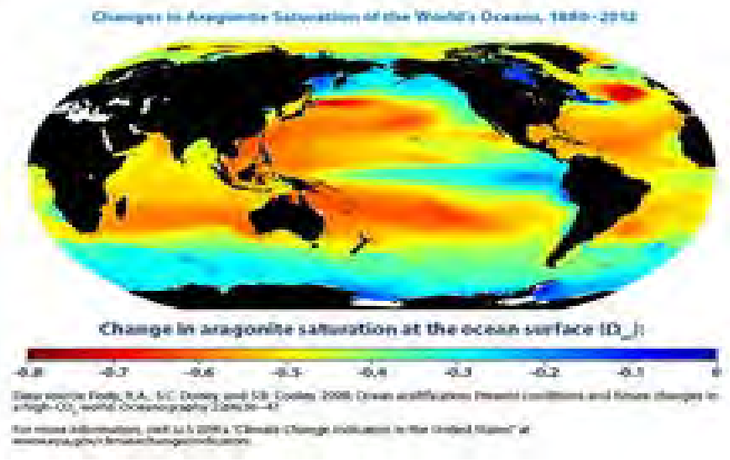
- Changing environments
- Climate confluence with human activities
- Building Climate into Management
  - Spatial Planning
  - Environmental Impact Assessment
- Science Diplomacy: A role for scientists and networks

The ocean as great climate mitigator

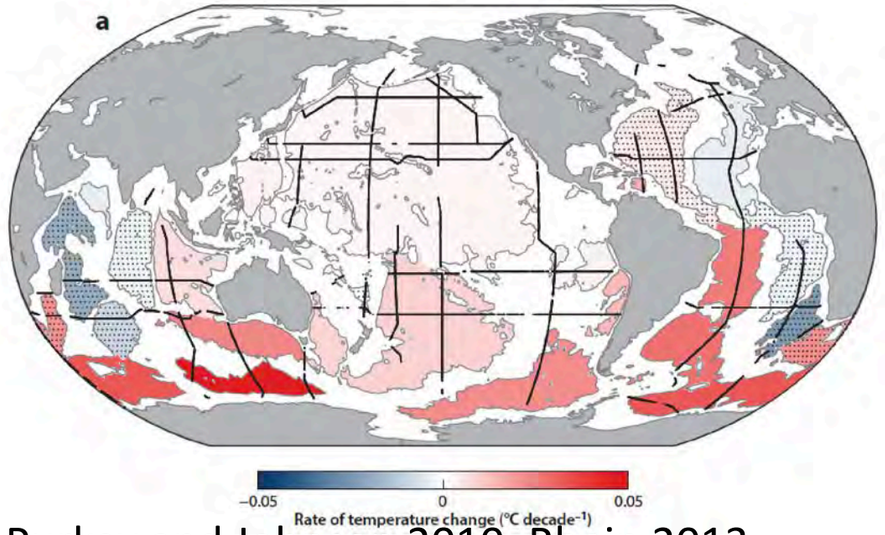


Thermohaline circulation and convection leads to a warmer, more acidic, less oxygenated ocean



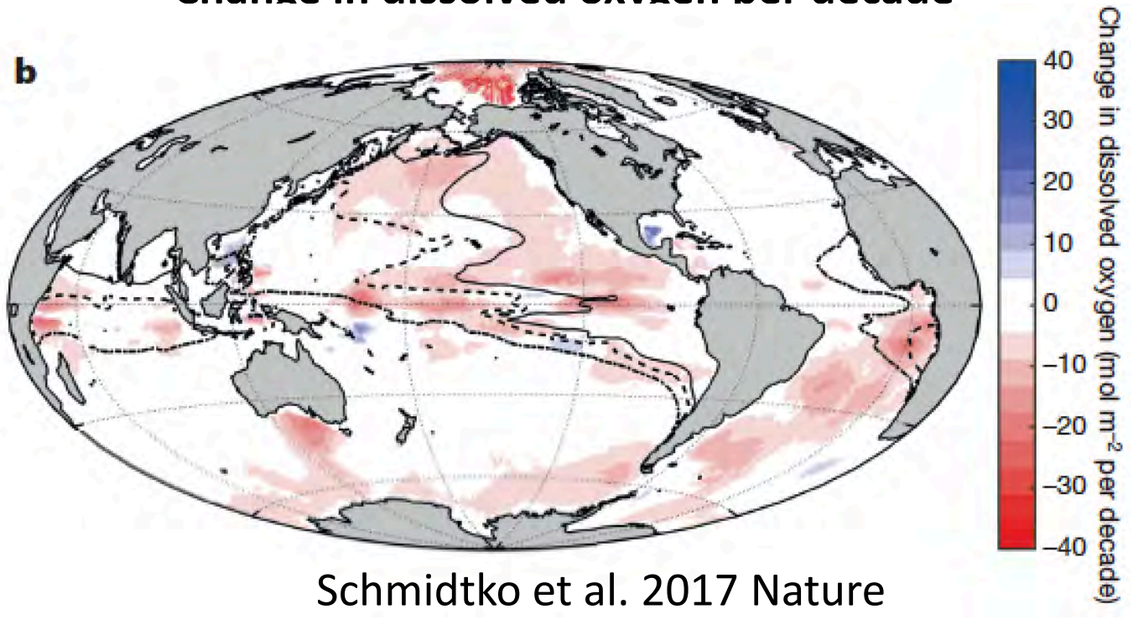


Abyssal Heat Uptake > 4000 m (1992-2005)



Purkey and Johnson 2010, Rhein 2013

Change in dissolved oxygen per decade

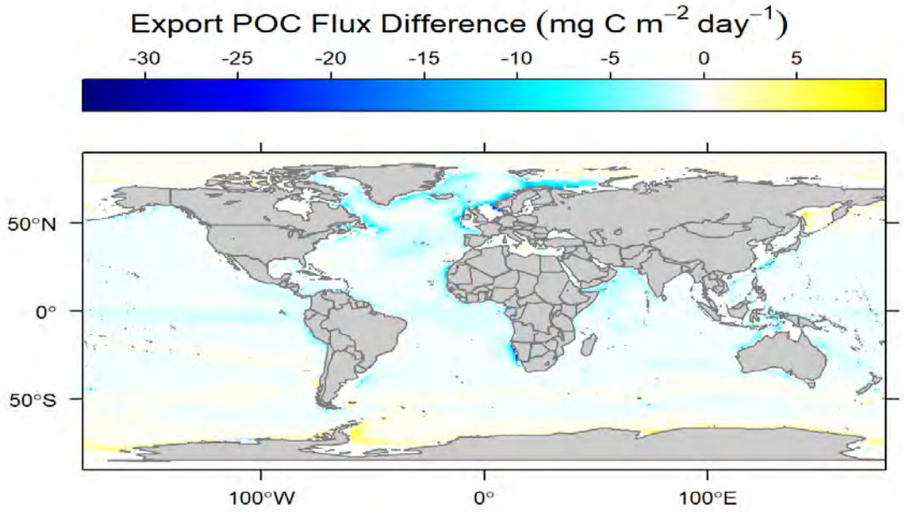


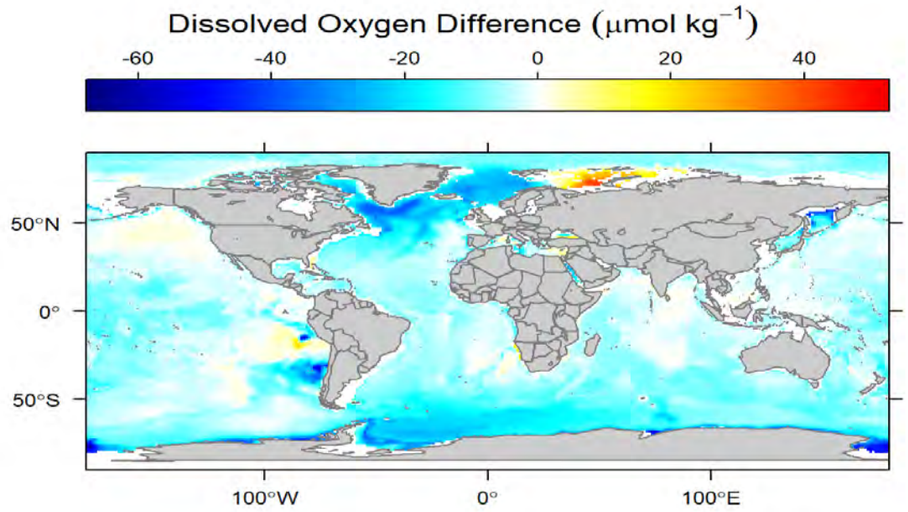
Schmidtko et al. 2017 Nature

Projected changes on the deep-sea floor

RCP 8.5 Change from 1951/2000 to 2080-2100 at the sea floor

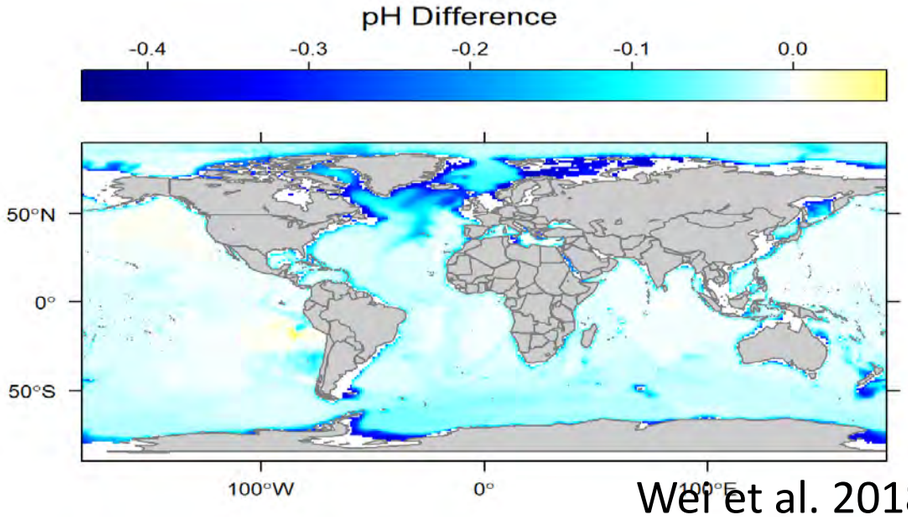
POC Flux

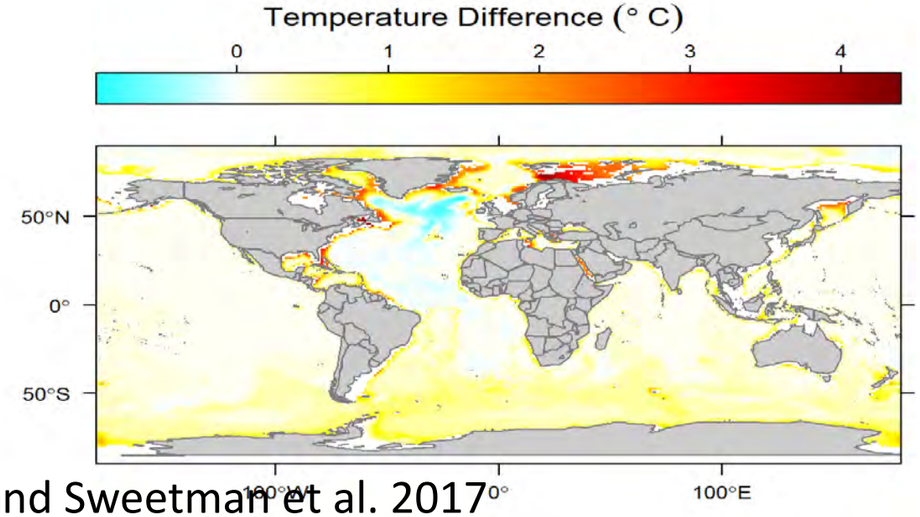




O_2

pH





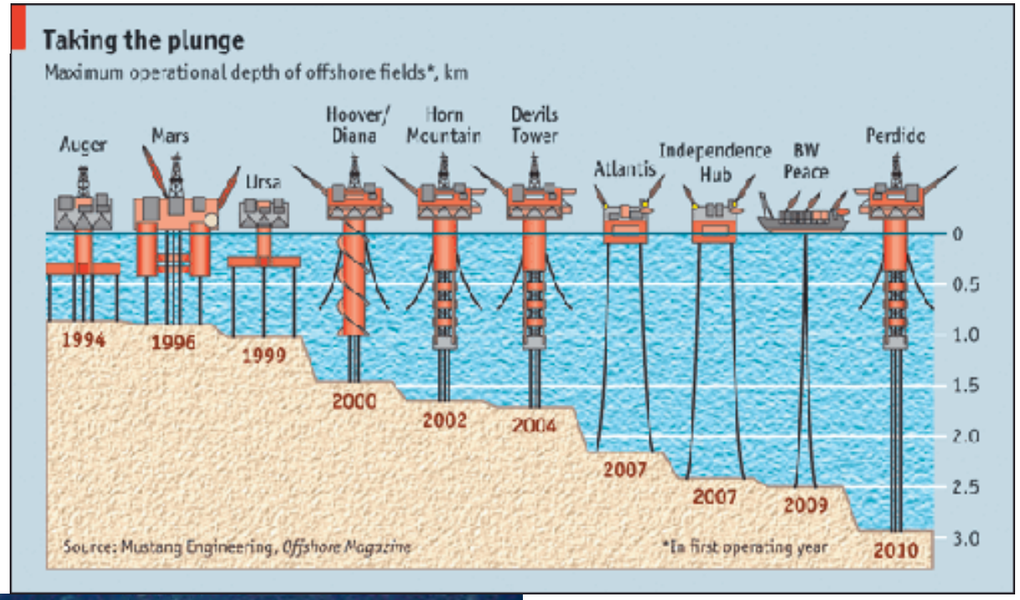
Temp

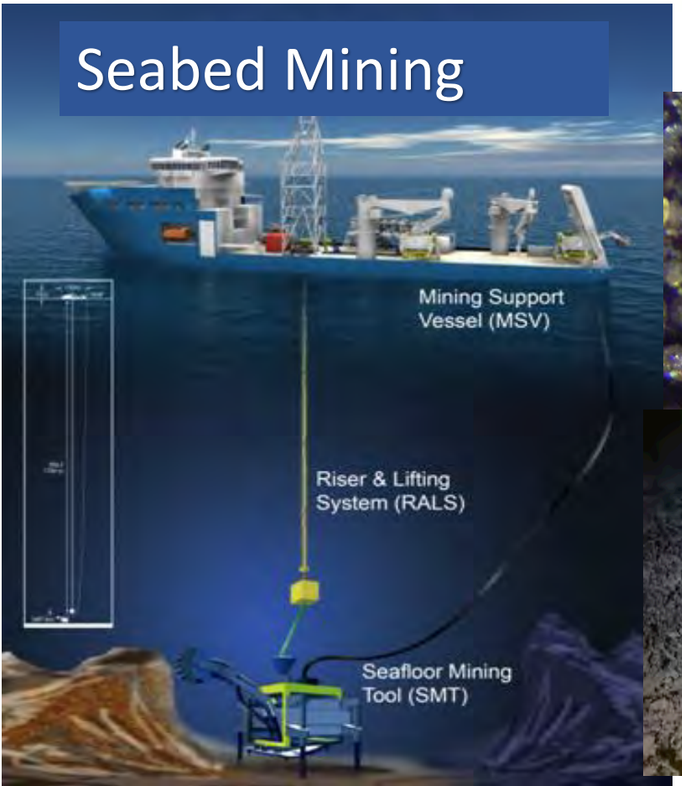
Wei et al. 2018 and Sweetman et al. 2017

Ch8, Deep-Ocean climate change impacts on habitat, fish and fisheries. **FAO**

Growing human pressures in the deep ocean …

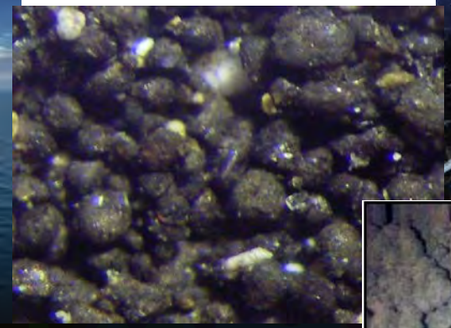
Oil and Gas Extraction

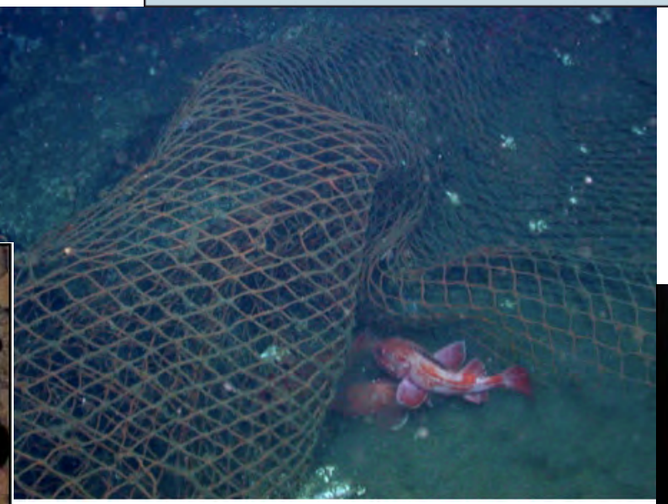




OMZs

Vents

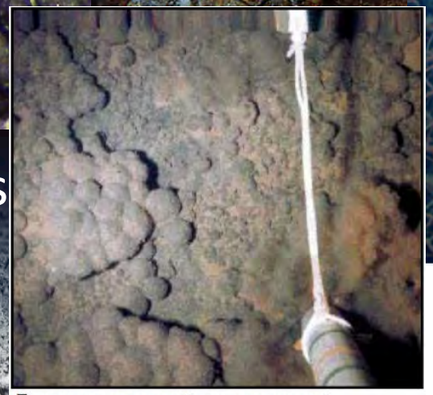




Mine tailings
Disposal

Debris

Abyssal plains



Ferromanganese crusts on a seamount (CoRMC-H, Auki)

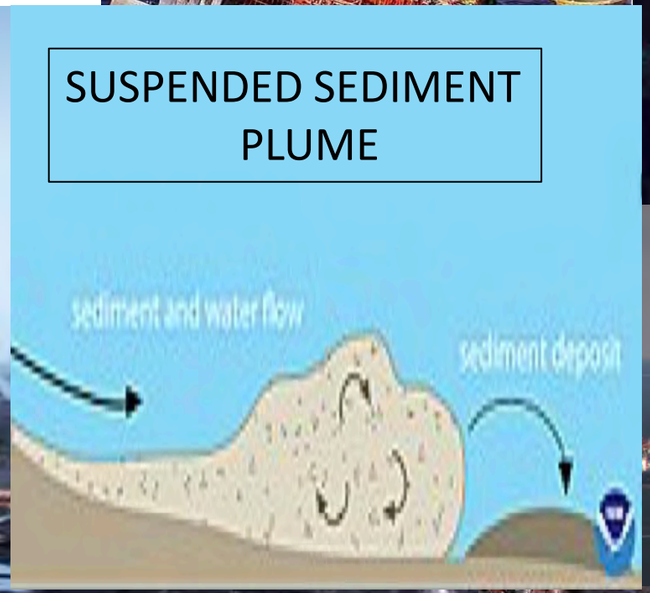
Seamounts

Bring disturbance…

ALTERED SUBSTRATE

PHYSICAL DISRUPTION

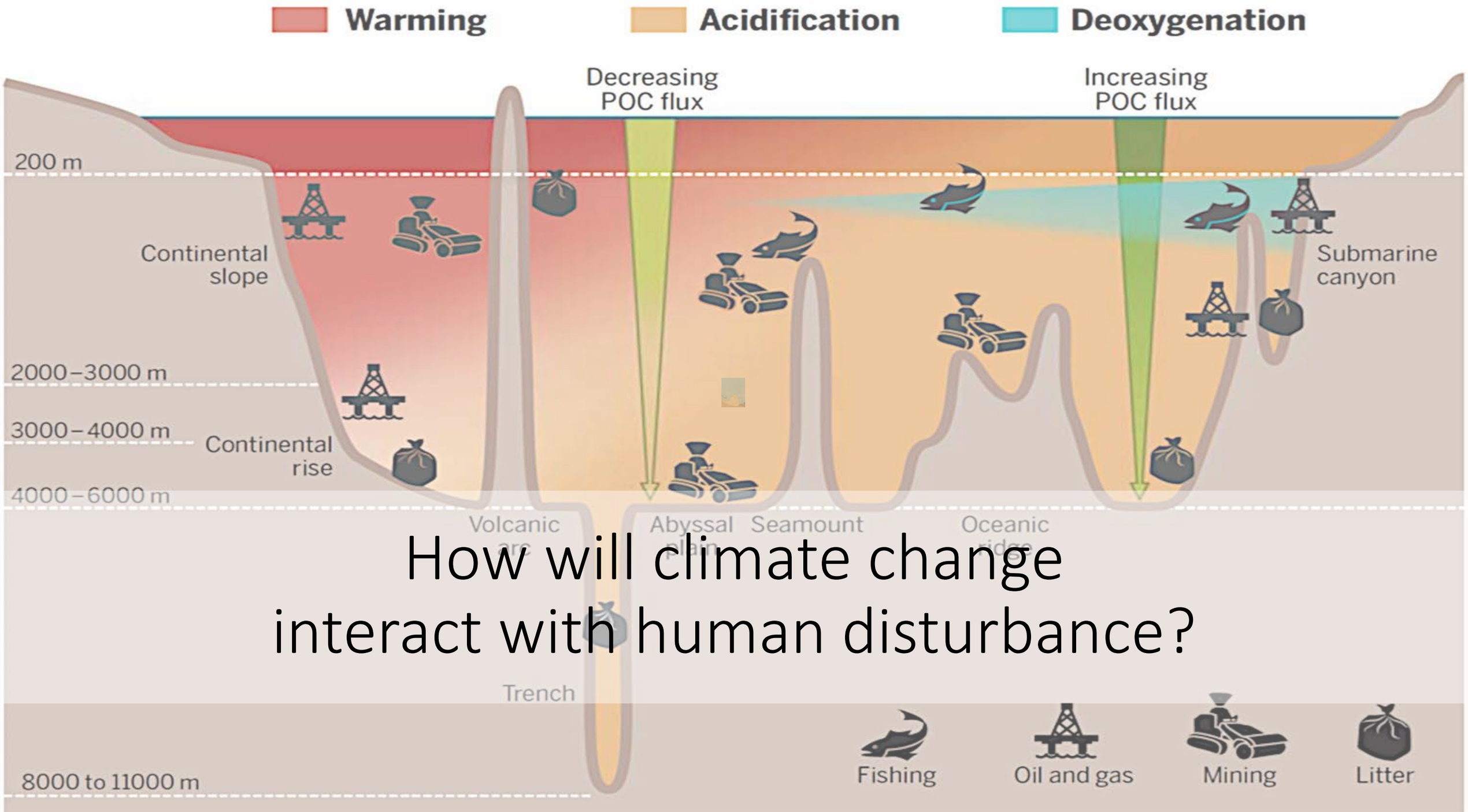
SUSPENDED SEDIMENT PLUME



CONTAMINATION

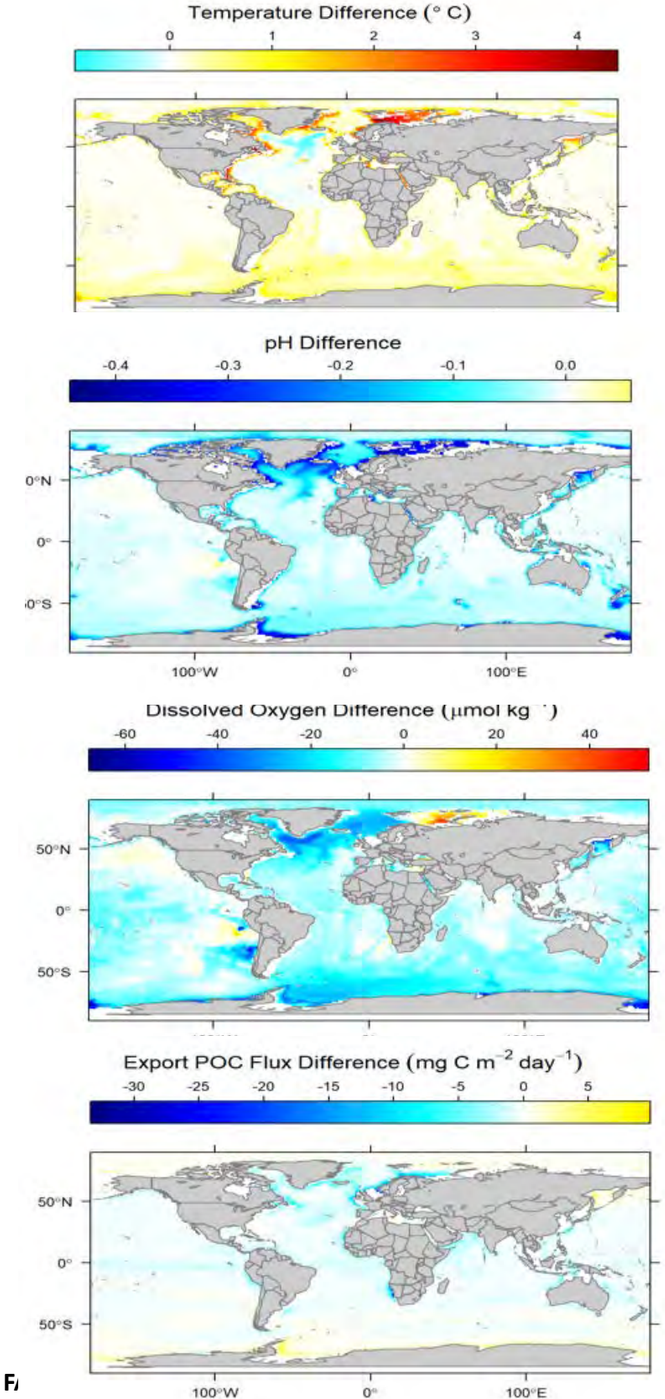
LOSS OF STRUCTURE

BYCATCH



How will climate change interact with human disturbance?

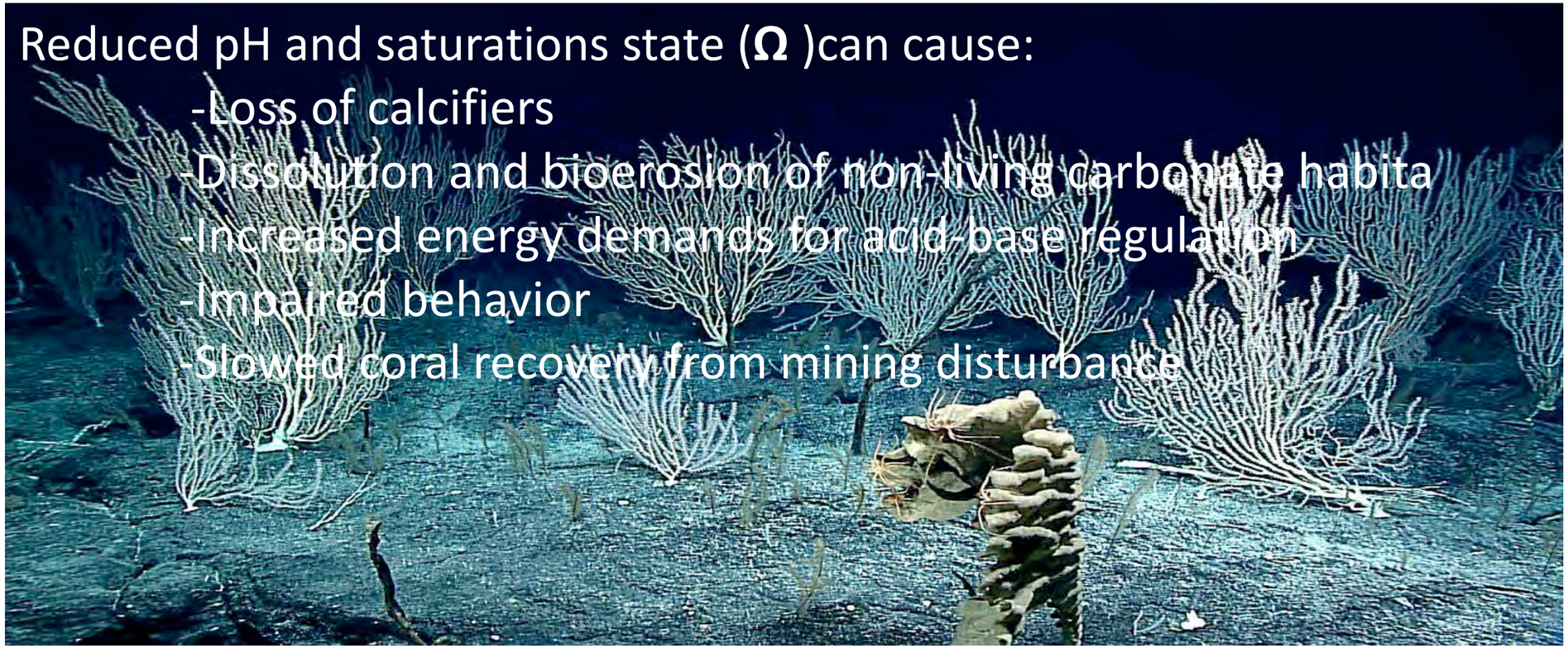
Temperature interaction with seabed mining

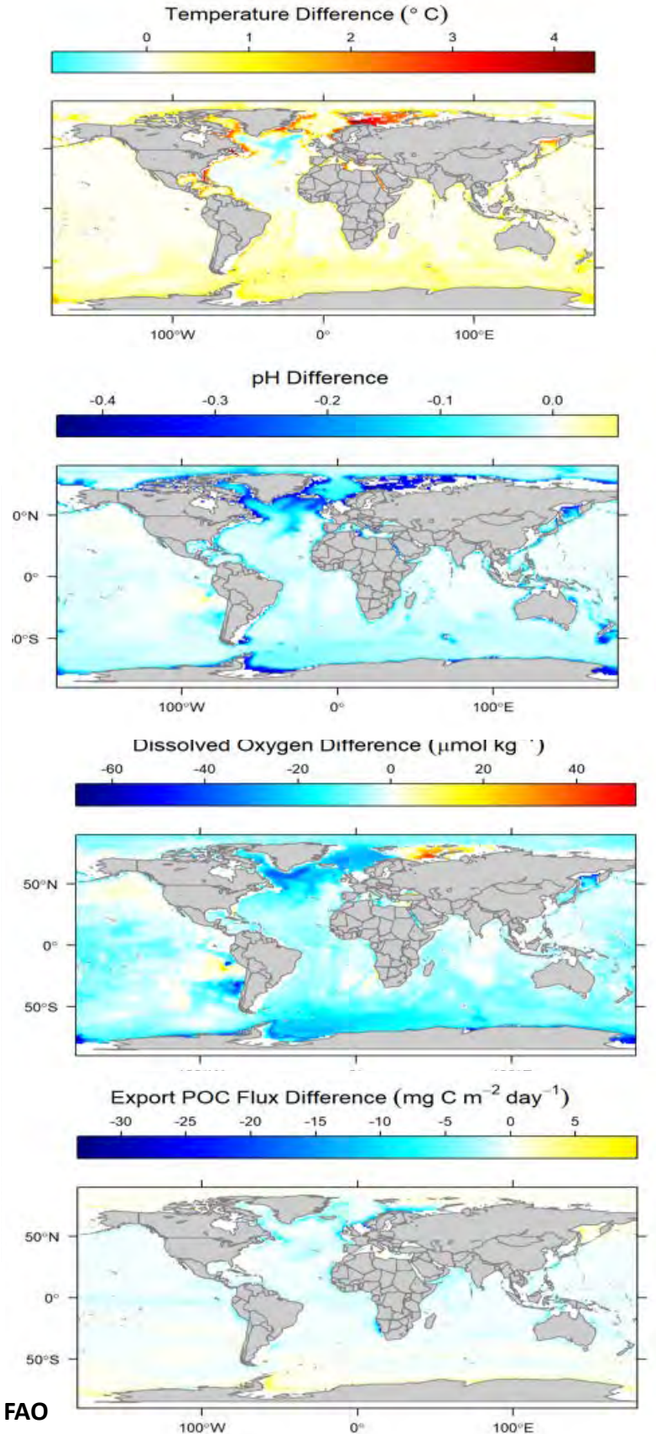


RCP 8.5 Change from 1951/2000 to 2080-2100

Wei et al. 2018

pH interaction with seabed mining





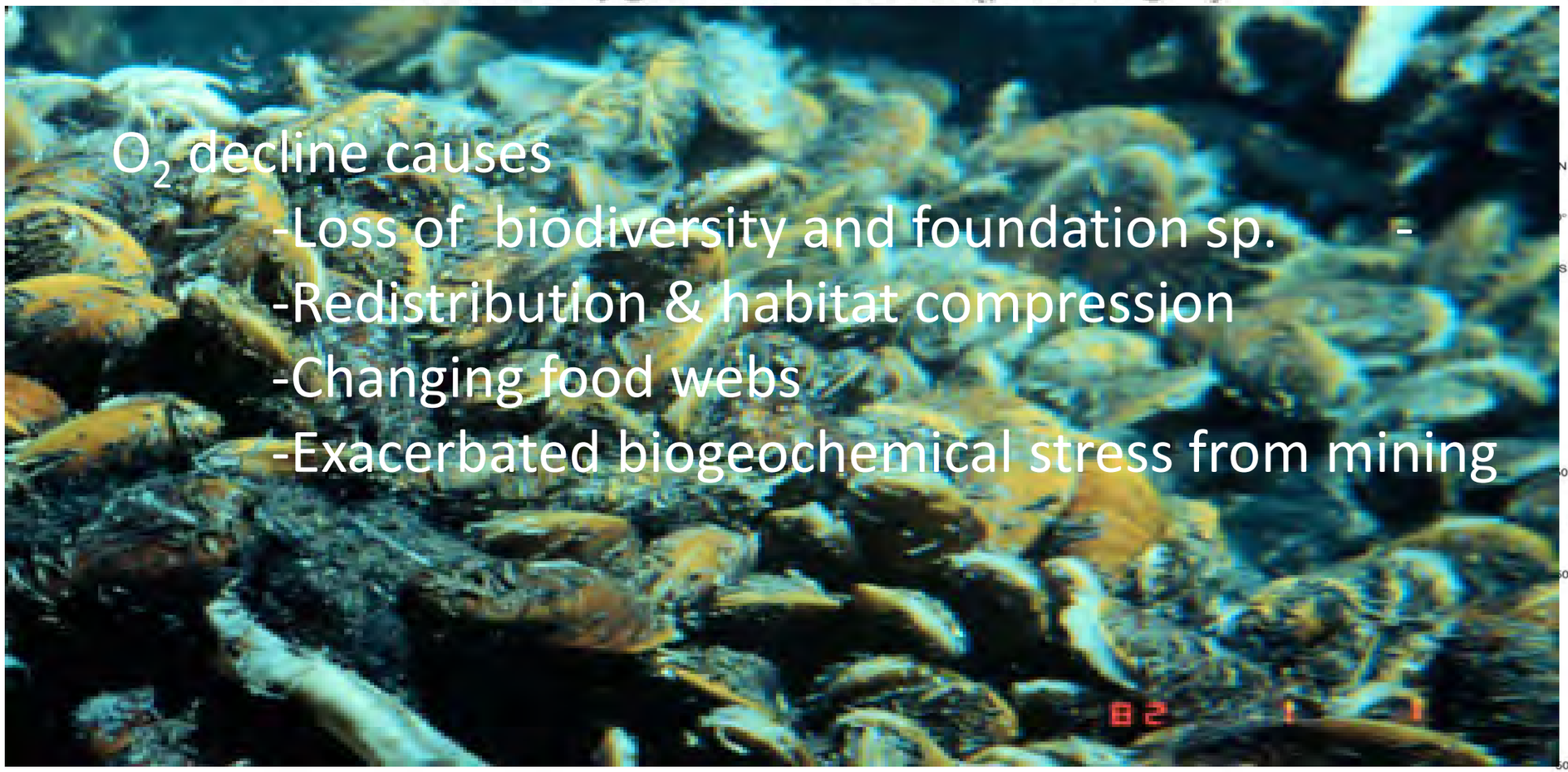
RCP 8.5 Change from 1951/2000 to 2080-2100

Wei et al. 2018

Ch8, Deep-Ocean climate change impacts on habitat, fish and fisheries. **FAO**

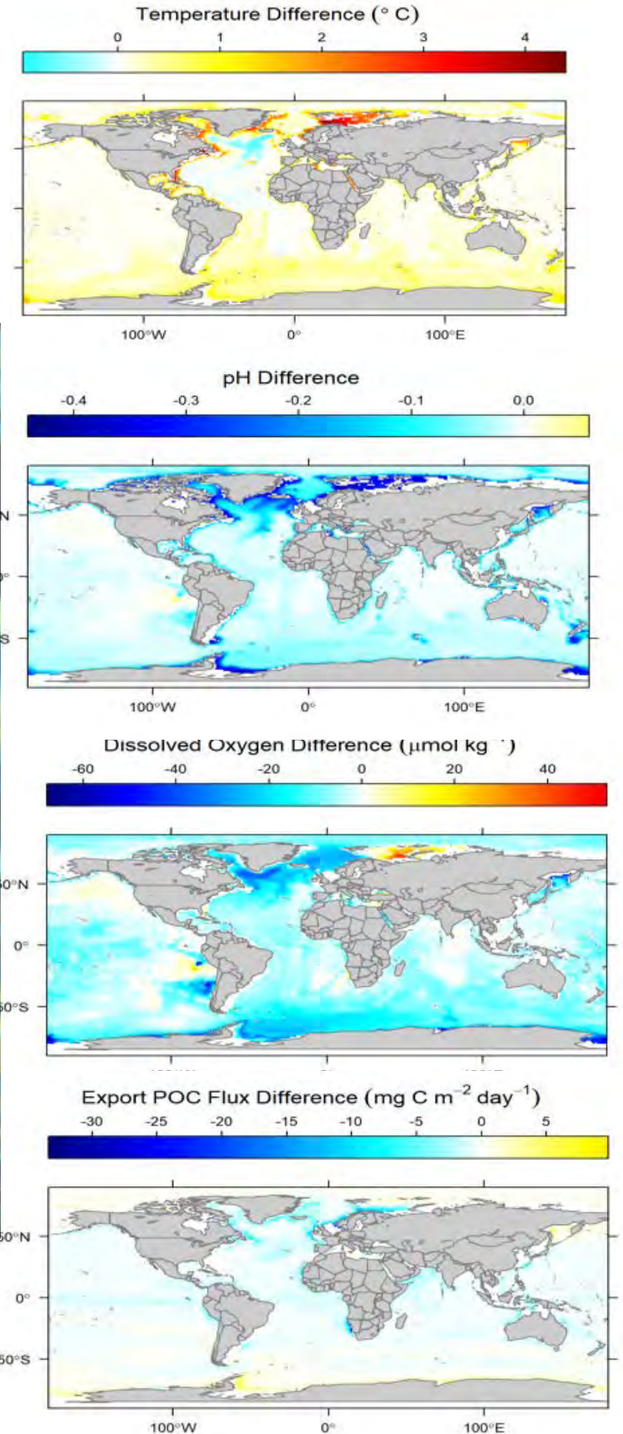
Oxygen interaction with seabed mining

Dissolved Oxygen Difference ($\mu mol\ kg^{-1}$)



O_2 decline causes

- -Loss of biodiversity and foundation sp.
- -Redistribution & habitat compression
- -Changing food webs
- -Exacerbated biogeochemical stress from mining

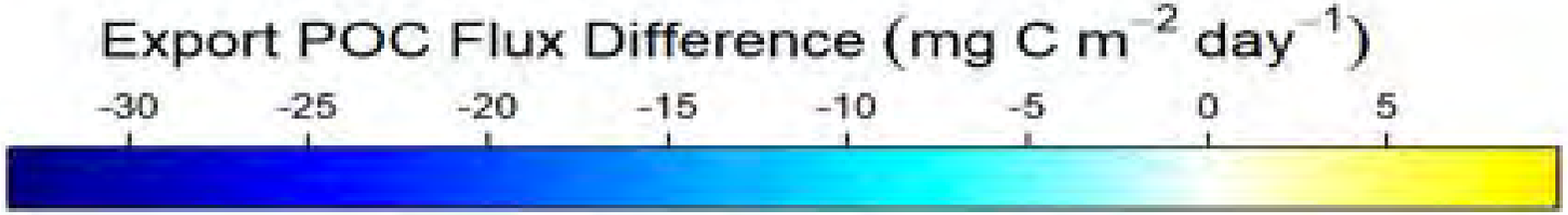


Wei et al. 2018

Ch8, Deep-Ocean climate change impacts on habitat, fish and fisheries. **FAO**

RCP 8.5 Change from 1951/2000 to 2080-2100

POC flux interaction with seabed mining

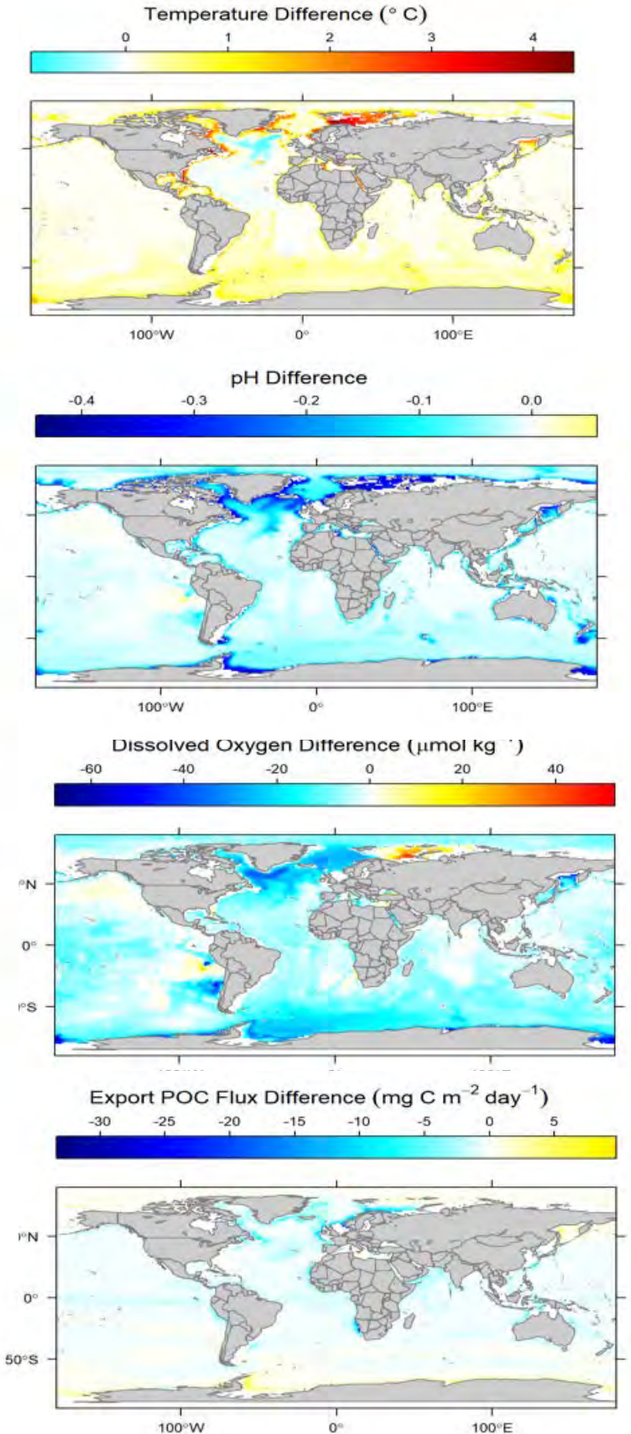


Reduced food supply can cause:

-Less biomass

-Smaller body size

-Problems coping with other stressors

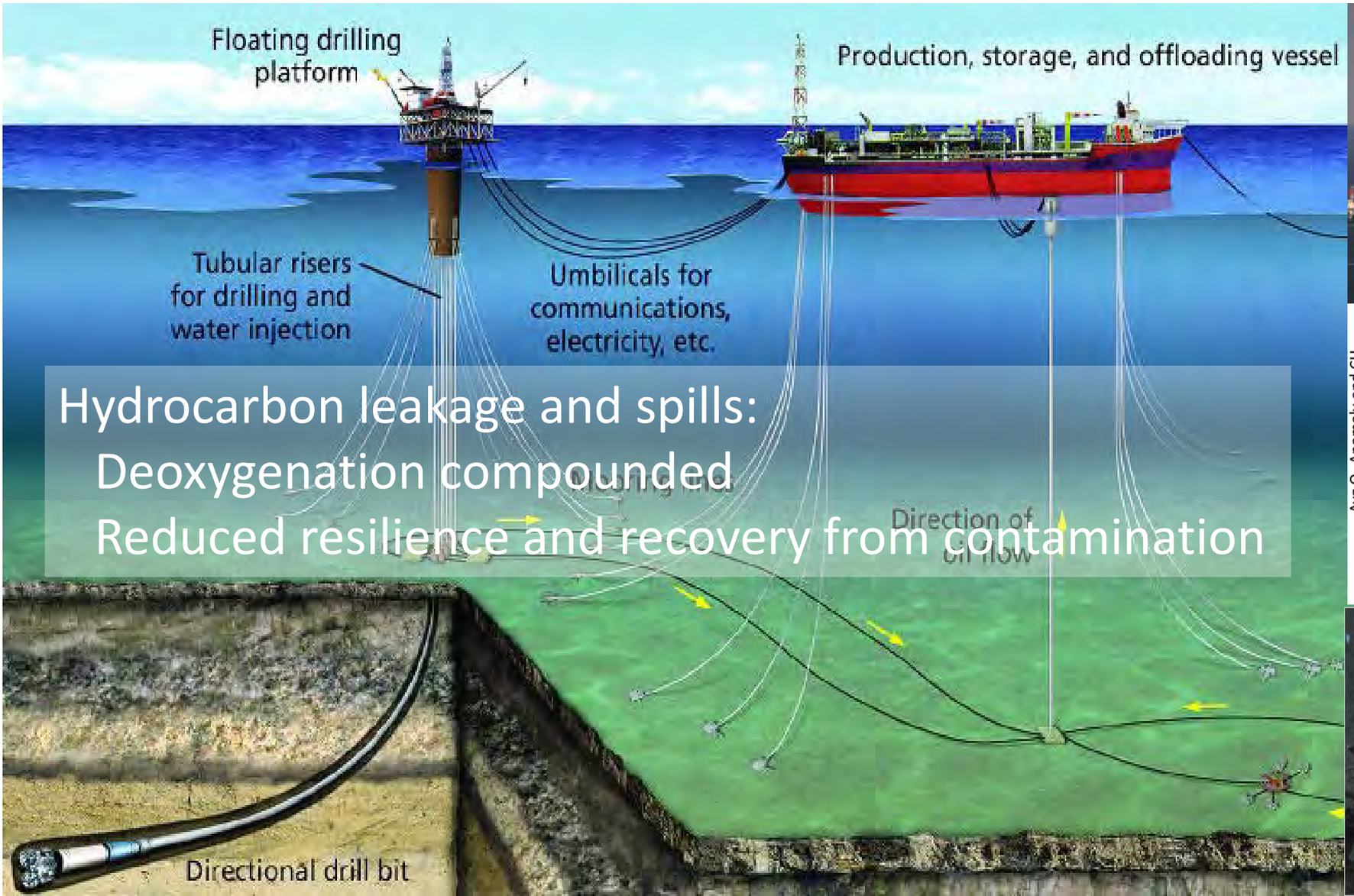


Wei et al. 2018

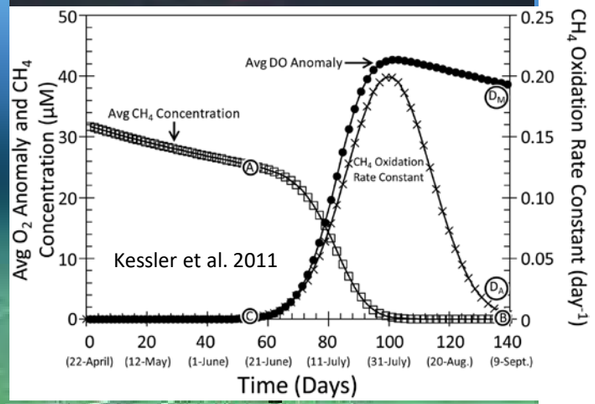
Ch8, Deep-Ocean climate change impacts on habitat, fish and fisheries. **FAO**

RCP 8.5 Change from 1951/2000 to 2080-2100

Climate change interaction with oil & gas activities

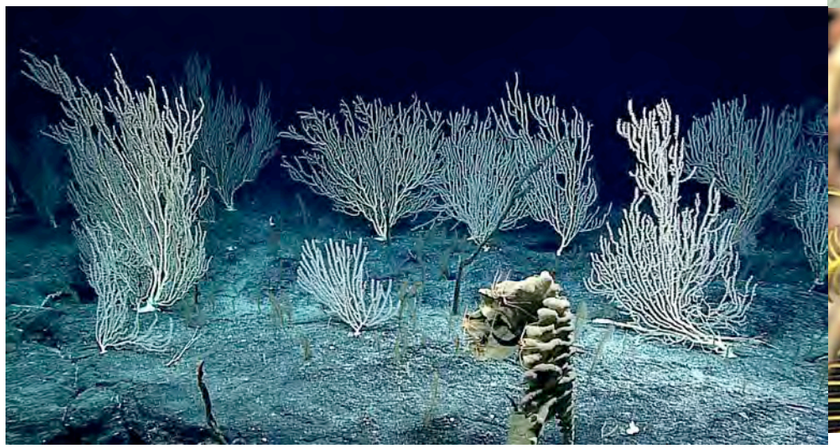


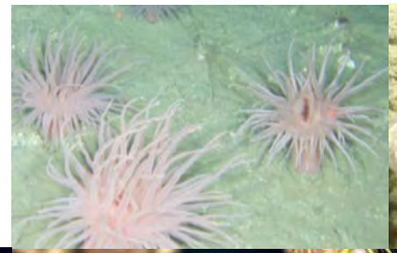
Hydrocarbon leakage and spills:
- Deoxygenation compounded
- Reduced resilience and recovery from contamination



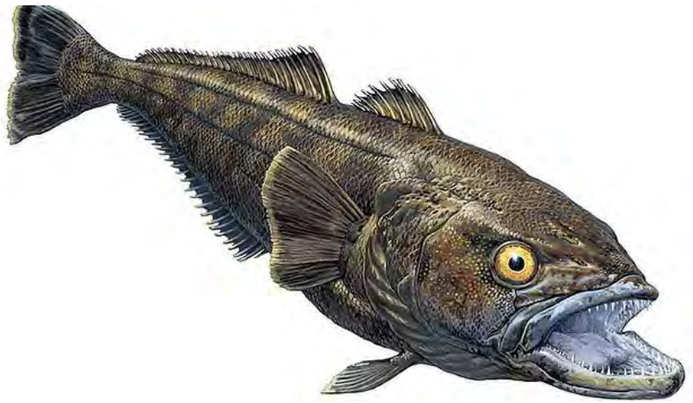
Climate change interaction with bottom fisheries

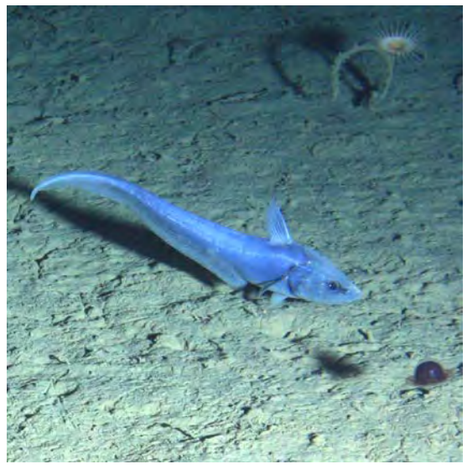
Vulnerable Marine Ecosystems





Fish: Habitat, Distributions, Body Size, Food webs

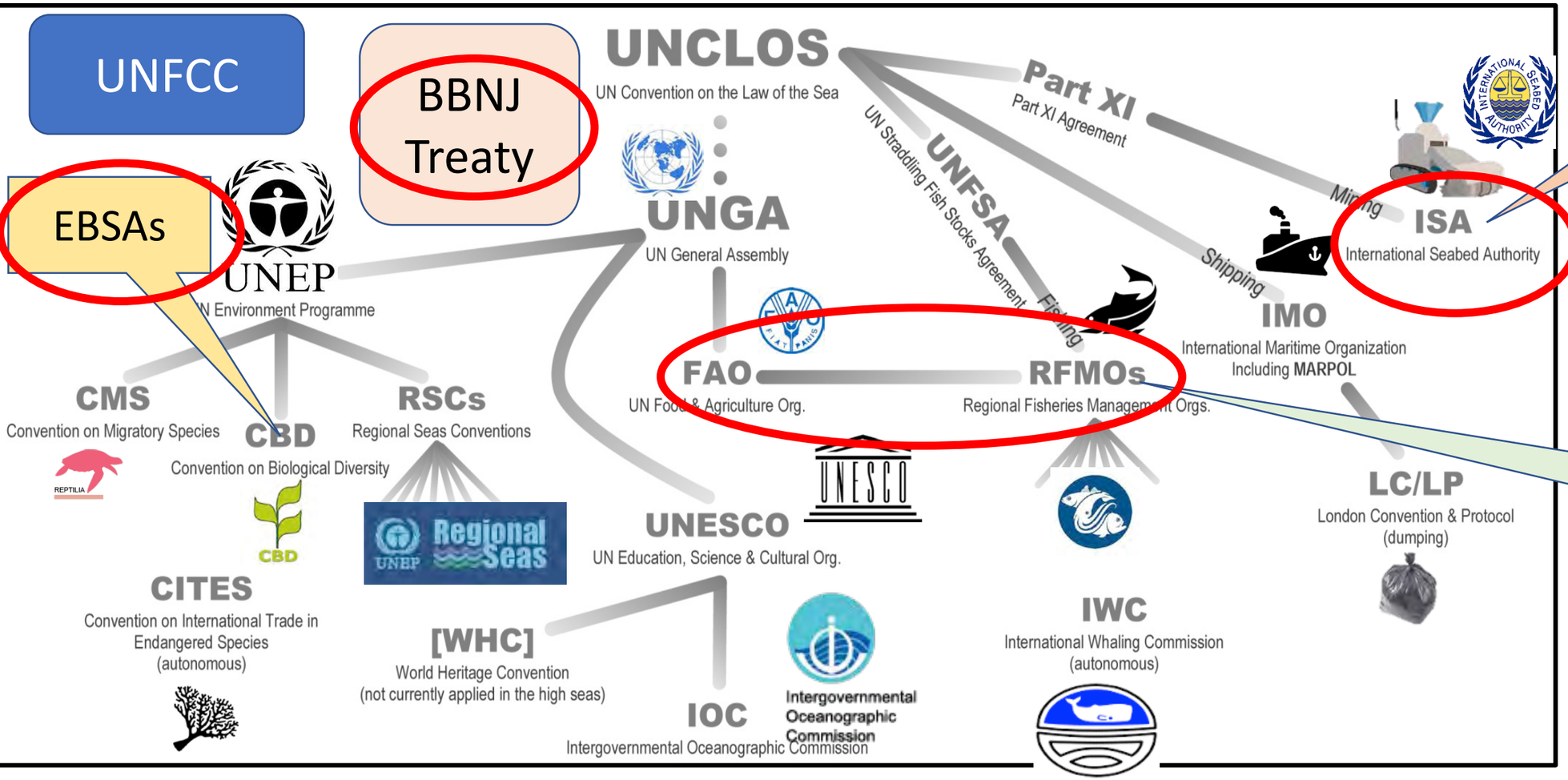




See S6 talks by
Morato
Carreiro-Silva
Cheung

How can we incorporate climate into management of the deep-sea floor?

International management of deep-ocean activities.



The seafloor in regions targeted for mining

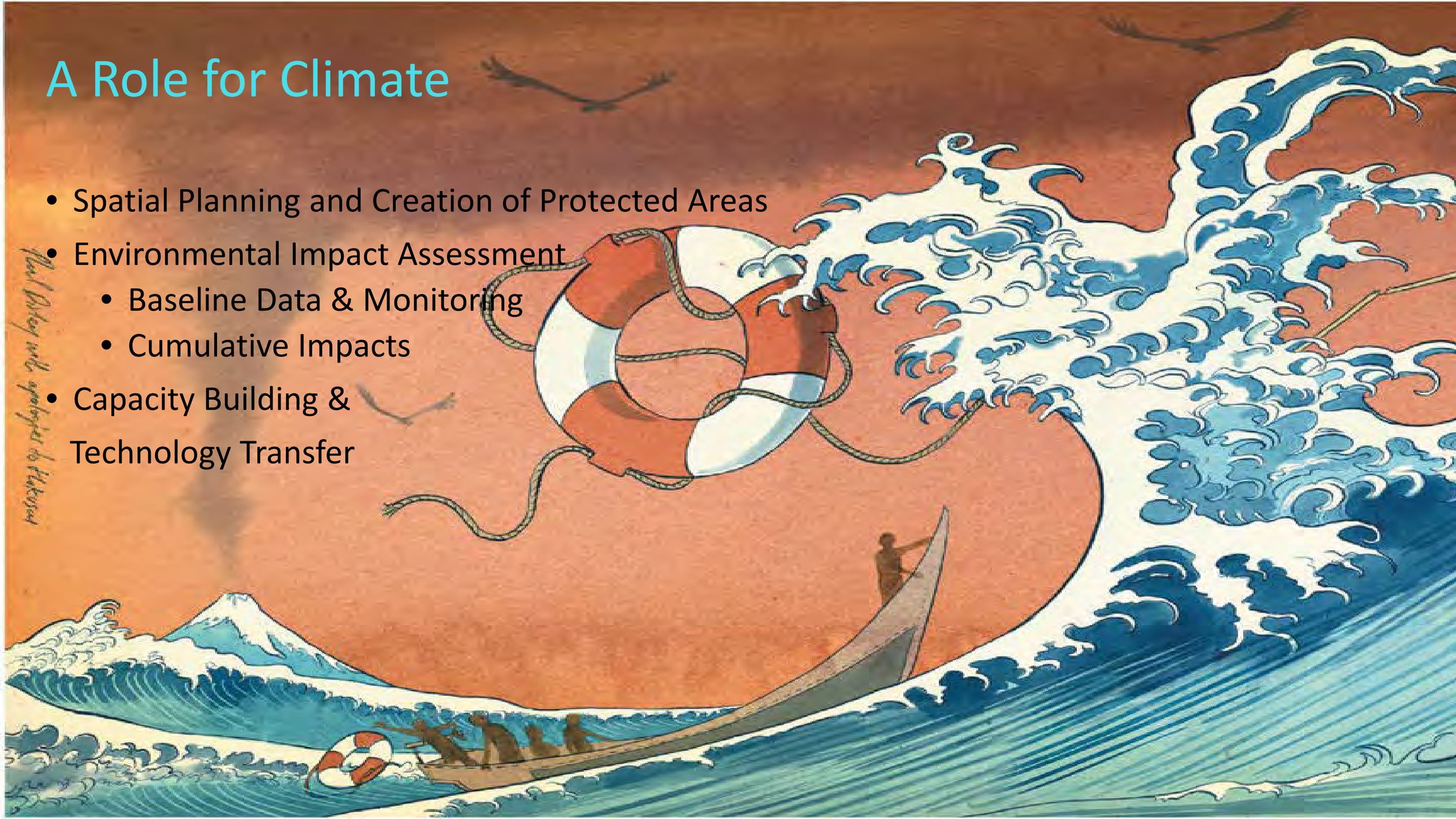
The seafloor in regions targeted for bottom fishing, tuna

Figure from chapter by Ardron & Warner, in Handbook of Ocean Resources, Earthscan Books

A Role for Climate

- Spatial Planning and Creation of Protected Areas
- Environmental Impact Assessment
  - Baseline Data & Monitoring
  - Cumulative Impacts
- Capacity Building &

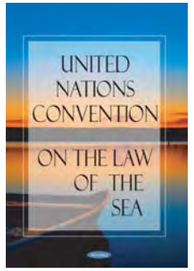
Technology Transfer



SEABED MINING

The International Seabed Authority has a mandate:

To adopt measures necessary to ensure effective protection of the marine environment



Areas of Particular Environmental Interest (APEIs) = no-mining areas

- Important Areas
- Representativity
- Connectivity
- Replication
- Viability & Adequacy

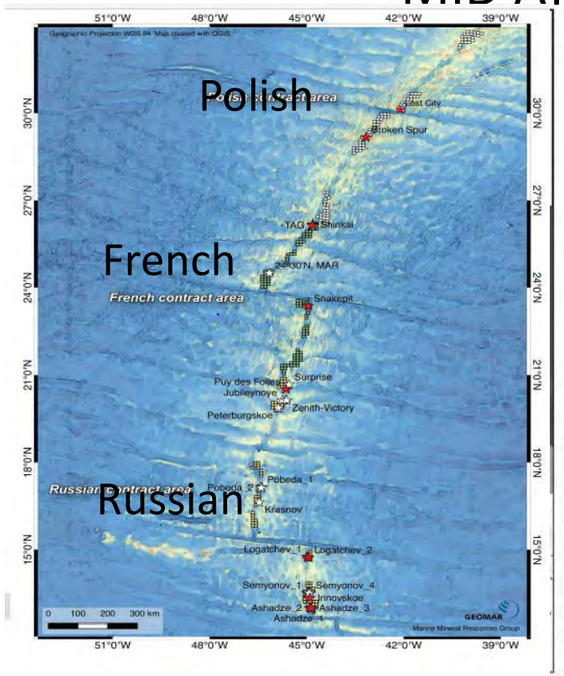
SEMPIA PLANNING

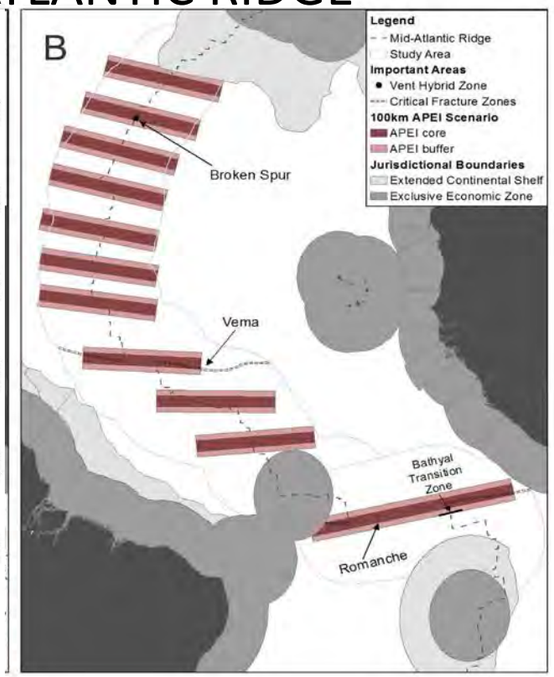
100, 200, 300, 400-km wide APEI scenarios

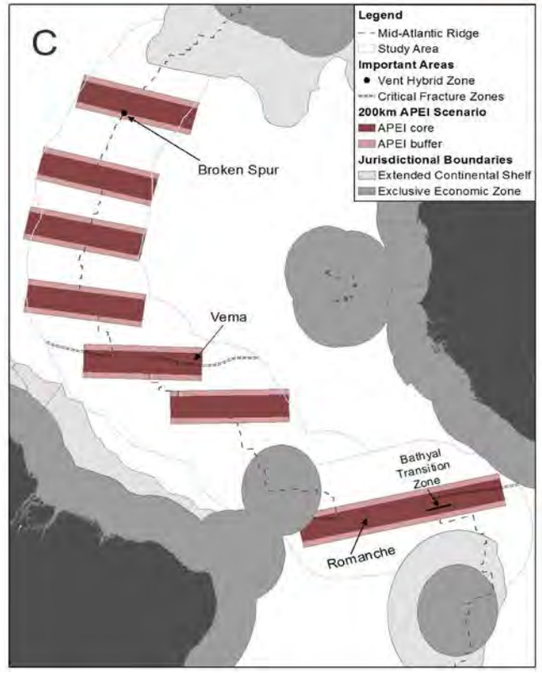
Incorporating projected climate change into assessment of different APEI scenarios

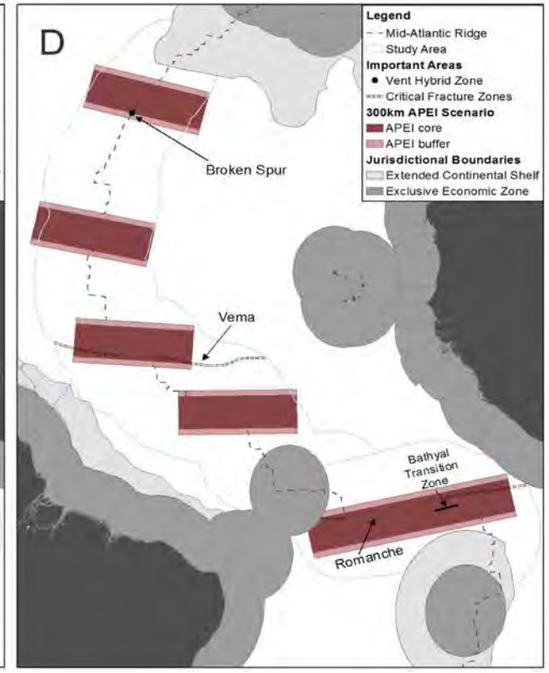
Dunn et al. in press
Science Advances

MID ATLANTIC RIDGE

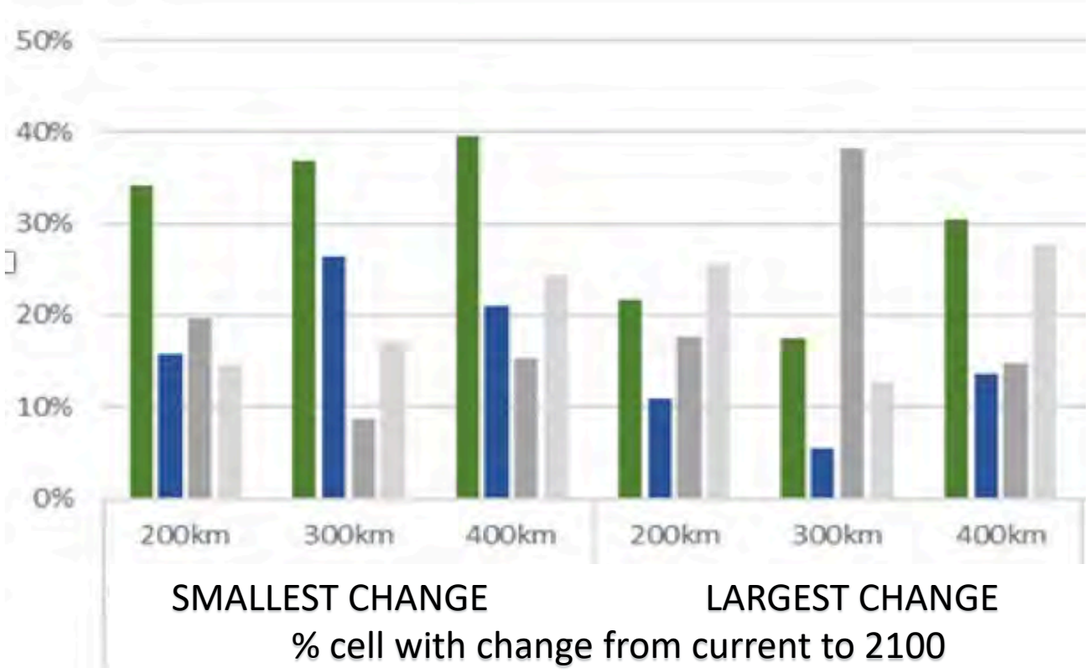








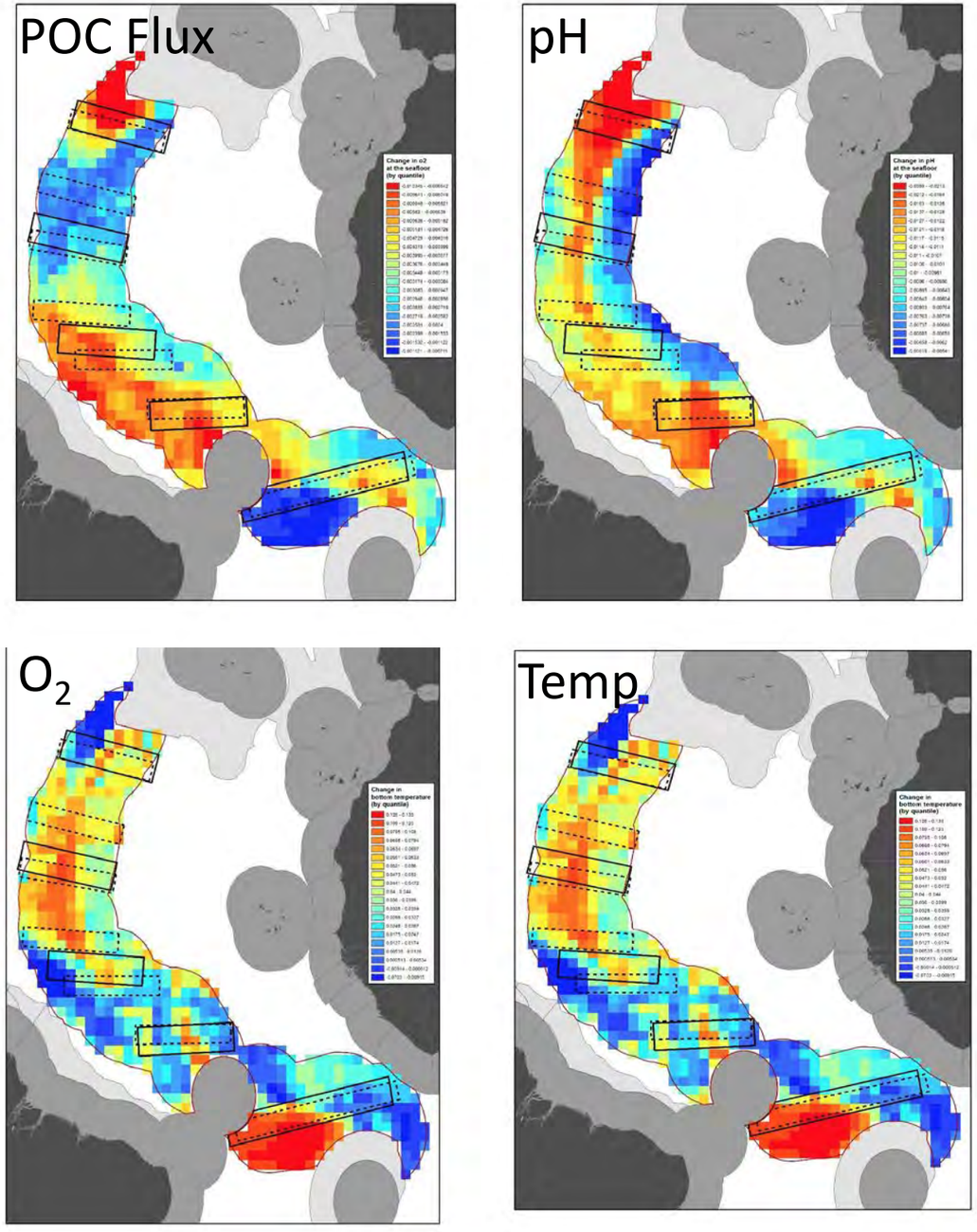
Projected Climate Change in 200, 300, 400-m wide APEI scenarios



Do we protect the least vulnerable areas as refugia?
or the most vulnerable areas to enhance resilience?

Dunn et al. in press, Science Advances
& Dunn, Wei, Levin et al. In prep.

MID ATLANTIC RIDGE



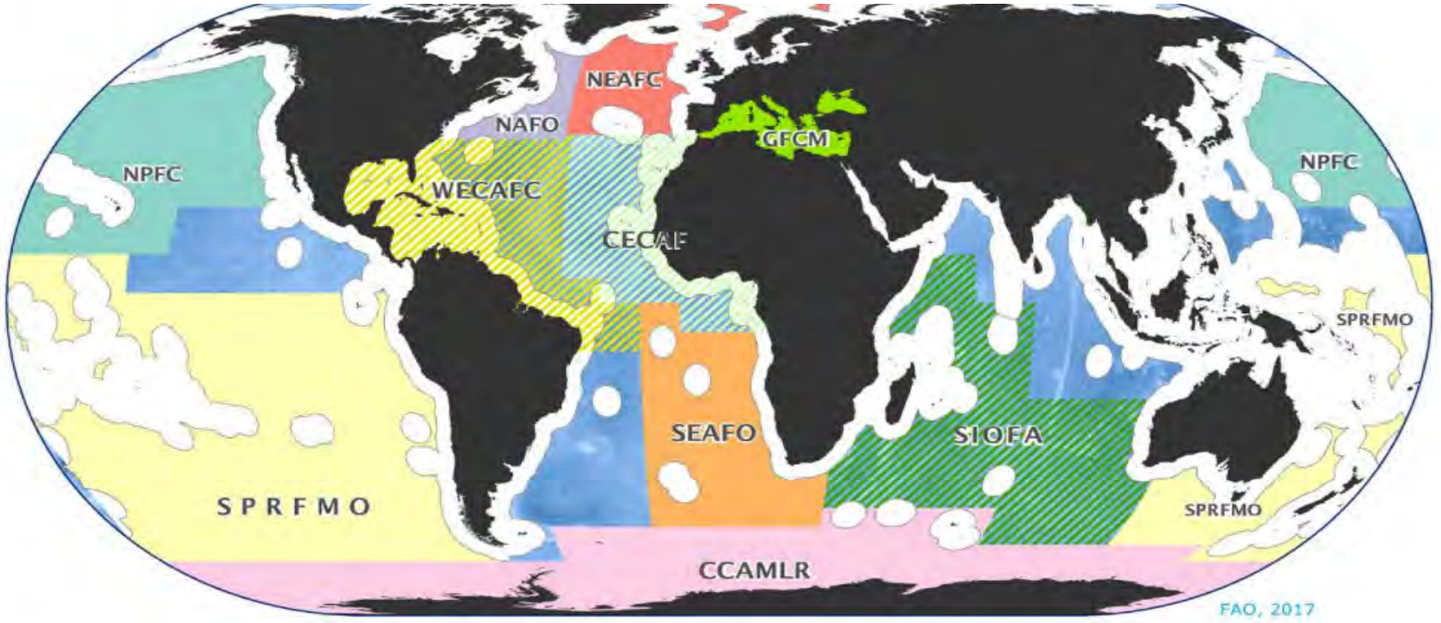
Projections under RCP 8.5 to 2100

Deep-sea Fisheries:
RFMOs must consider climate change impacts

Nature.com

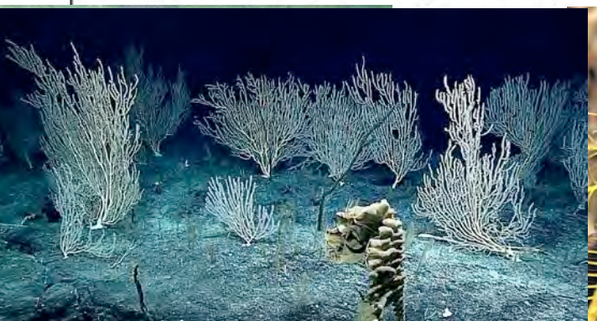
FIGURE 1

Regional Fisheries Management Organizations

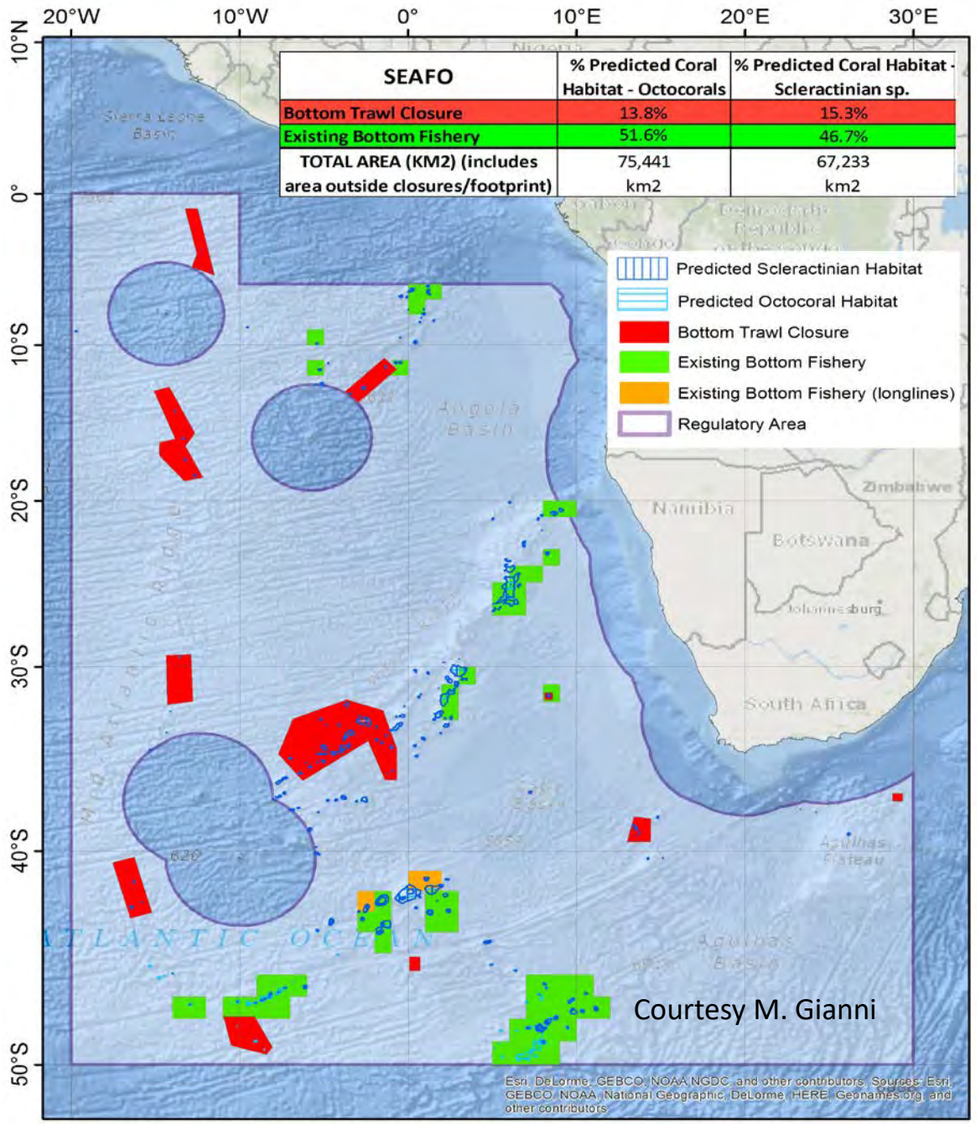


United Nations General Assembly resolution 71/123 2016

Paragraph 185. Calls upon States, individually and through regional fisheries management organizations and arrangements, *"to take into account the potential impacts of climate change and ocean acidification in taking measures to manage deep-sea fisheries and protect vulnerable marine ecosystems"*



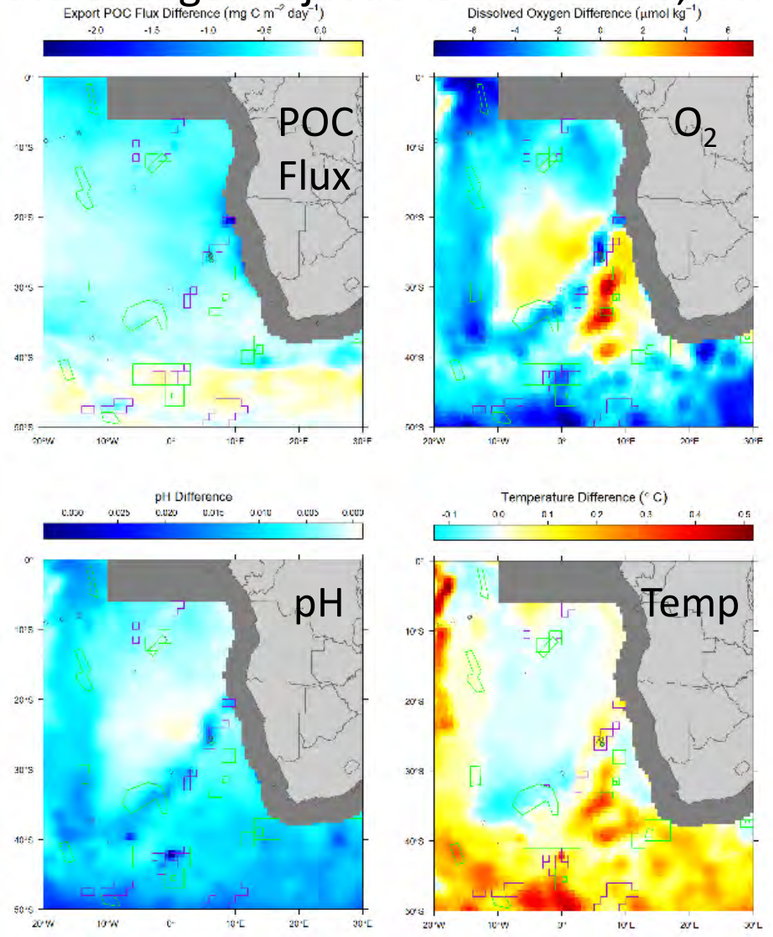
Southeast Atlantic Fisheries Organization



Courtesy M. Gianni

SEAFO	POC Flux	Oxygen	pH	Temperature
>200 m	-0.2	-0.01	0.07	0.07
200-2,500 m	-0.3	-0.01	0.1	0.1
Bottom fishing area	-0.17	-0.01	0.09	0.09
VME closed area	-0.14	-0.01	0.06	0.06
Seamounts	-0.18	-0.01	0.07	0.07
Cold-water corals	-0.52	-0.01	0.06	0.06
Canyons	-0.29	-0.01	0.1	0.1

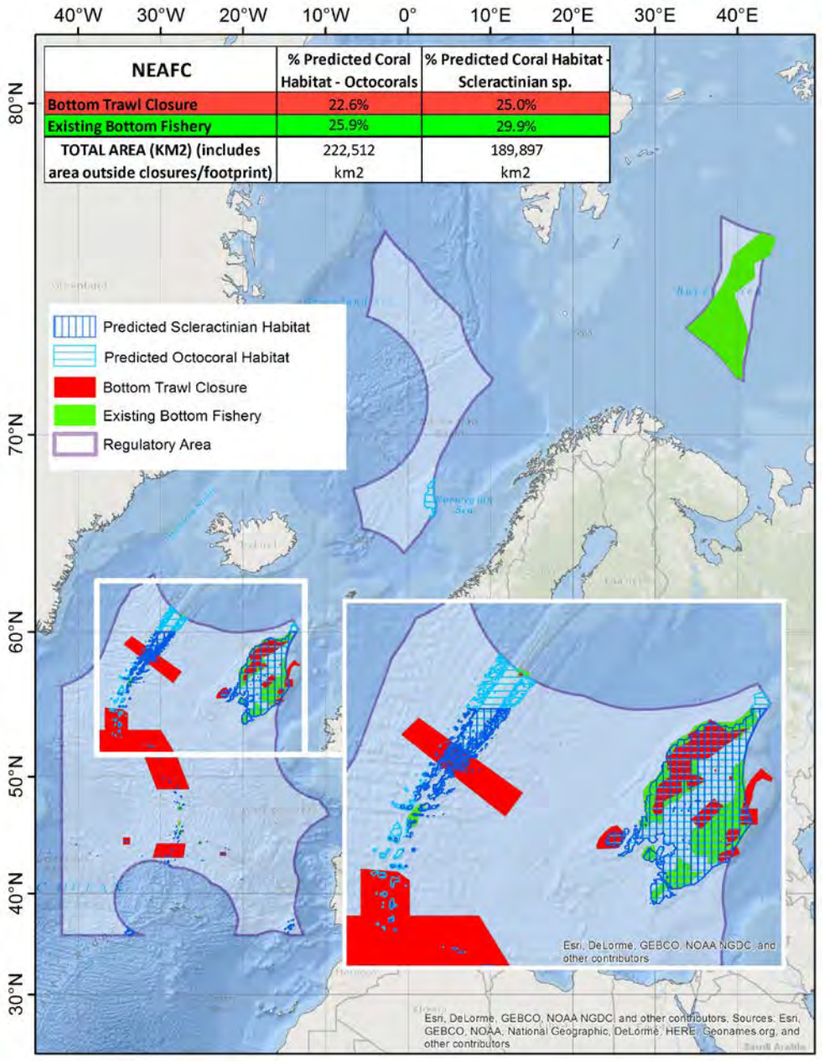
Climate Change Projections 2041-2060, RCP 8.5



Wei et al. 2018

Ch8, Deep-ocean climate change impacts on habitat, fish and fisheries. **FAO**

Northeast Atlantic Fisheries Commission

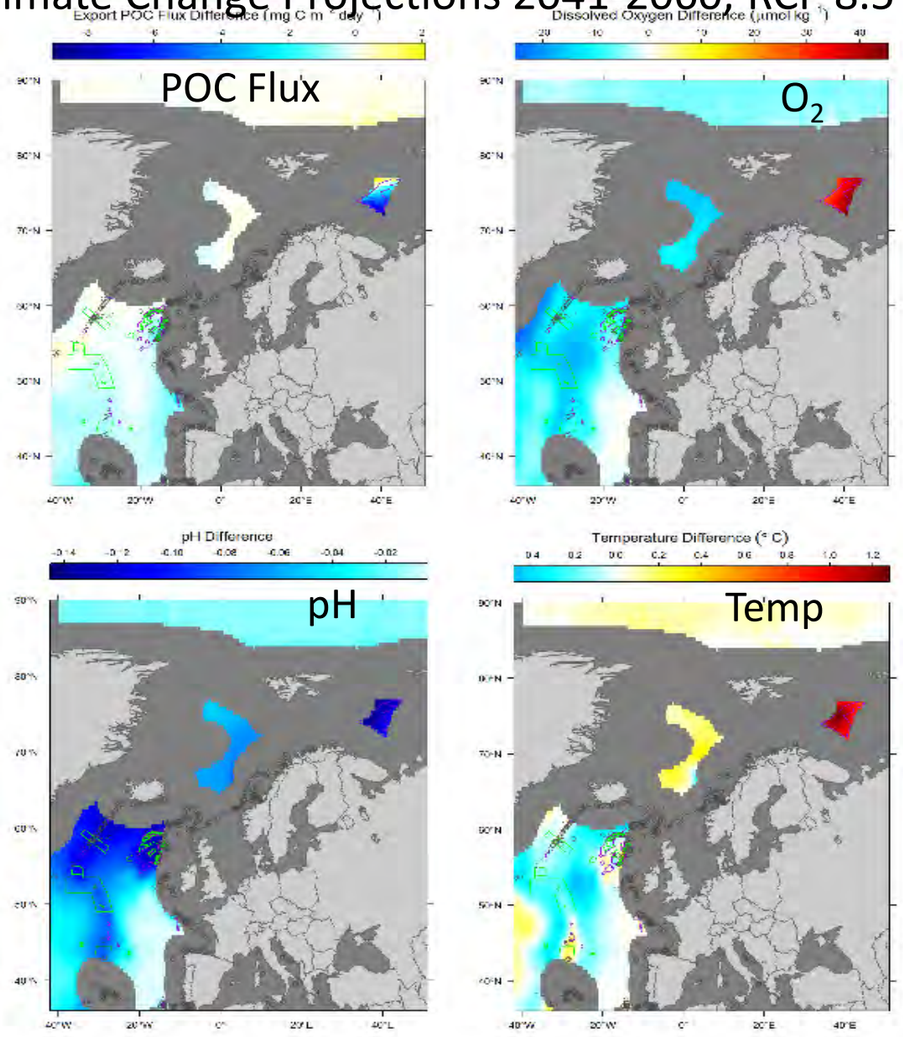


Wei et al. 2018

Ch8, Deep-Ocean climate change impacts on habitat, fish and fisheries. **FAO**

NEAFC	POC Flux	Oxygen	pH	Temperature
>200 m	-0.22	-7.11	-0.04	-0.01
200-2 500 m	-0.62	-4.42	-0.11	0.11
Bottom fishing area	-2.2	13.9	-0.12	0.56
VME closed area	-0.27	-13.51	-0.09	-0.14
Cold-water corals	-0.44	-10.23	-0.1	0.01
Canyons	-0.58	-8.74	-0.09	-0.05

Climate Change Projections 2041-2060, RCP 8.5



Time of Emergence

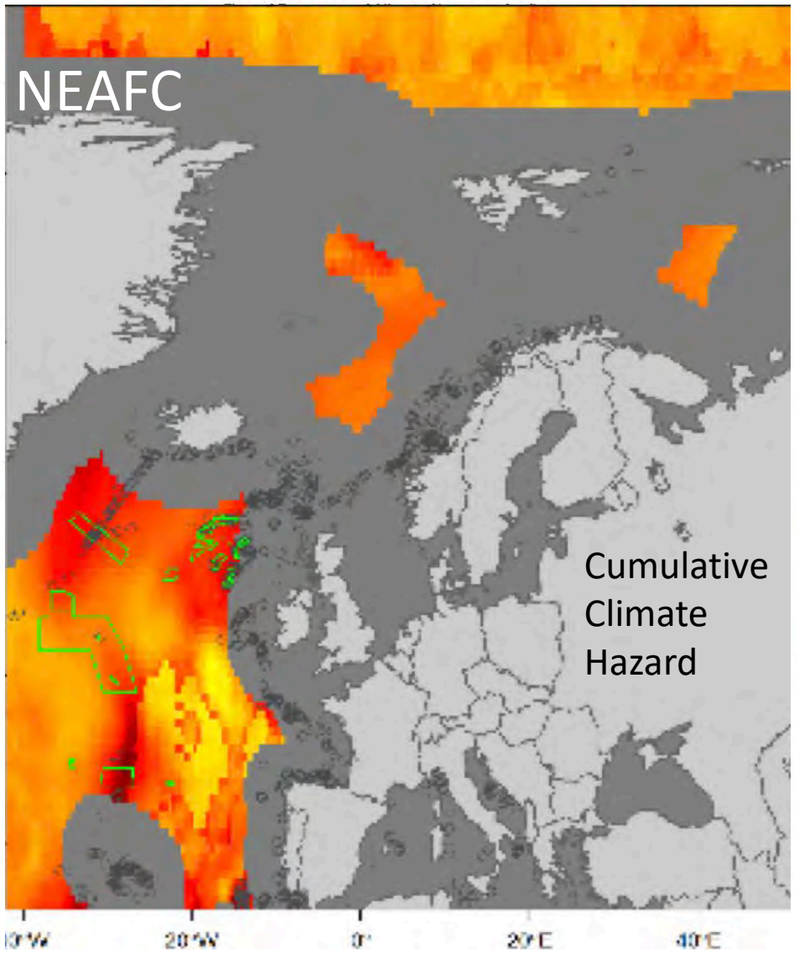
(when the climate signal exceeds natural variability)

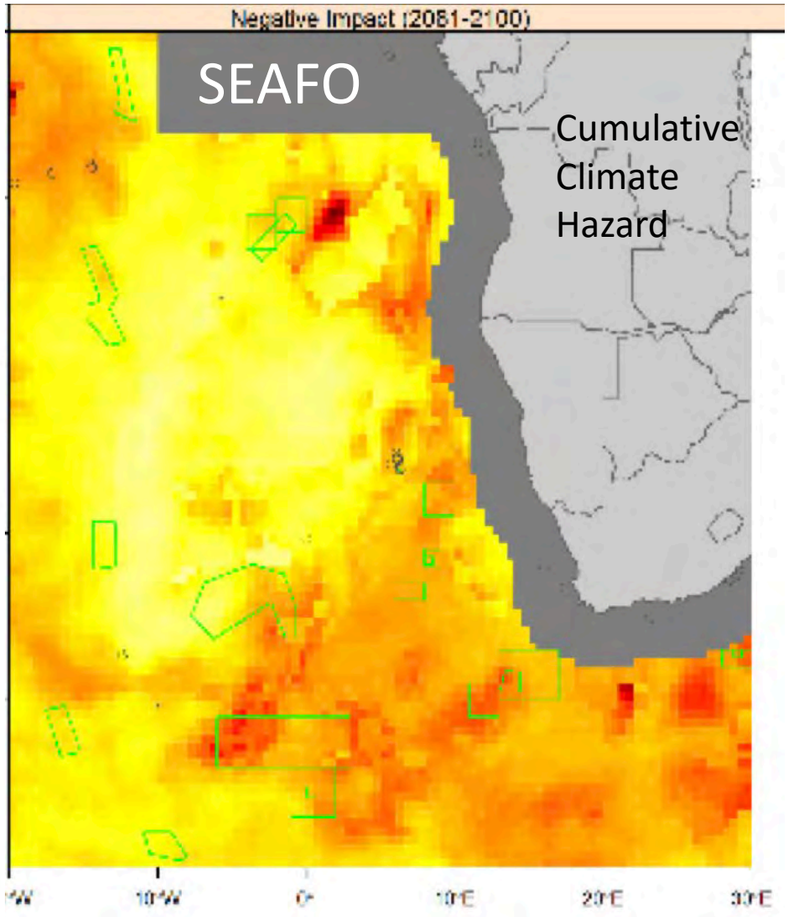
- Identify the most imminent threats
- Identify areas with least change to act as refugia

All areas will exceed natural variability for all parameters before 2060

NEAFC	POC Flux	Oxygen	pH	Temperature
>200 m	2057	2044	2044	2050
200-2 500 m	2048	2045	2030	2041
Bottom fishing area	2051	2037	2028	2027
VME closed area	2048	2043	2029	2037
Cold-water corals	2052	2049	2032	2041
Canyons	2043	2043	2031	2040

SEAFO	POC Flux	Oxygen	pH	Temperature
>200 m	2047	2046	2042	2050
200-2 500 m	2048	2039	2039	2041
Bottom fishing area	2042	2040	2039	2048
VME closed area	2044	2044	2041	2053
Seamounts	2040	2040	2042	2053
Cold-water corals	2046	2048	2044	2042
Canyons	2046	2040	2037	2044





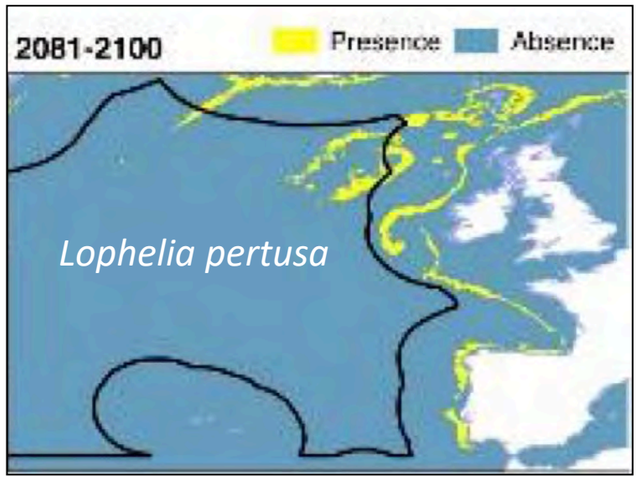
Wei et al. 2018

Ch8, Deep-Ocean climate change impacts on habitat, fish and fisheries. **FAO**

Climate and Spatial Planning

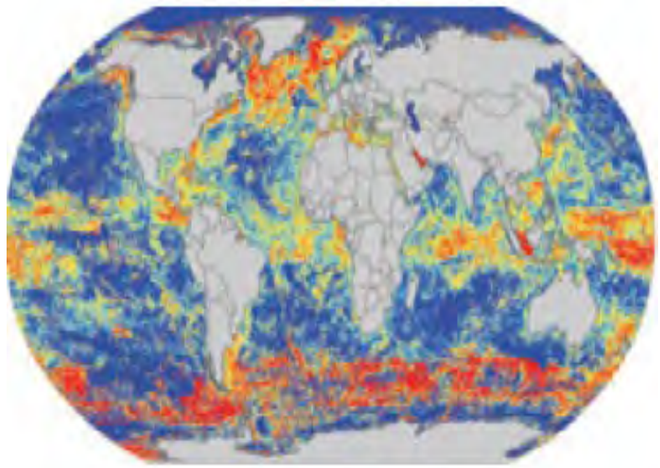
- Climate change can affect connectivity of populations and protected areas.

- Climate change can alter habitat suitability, redistribute species, alter biomass and modify biodiversity.



Ch 10 Morato et al. in ***Deep-Ocean climate change impacts on habitat, fish and fisheries.*** **FAO**

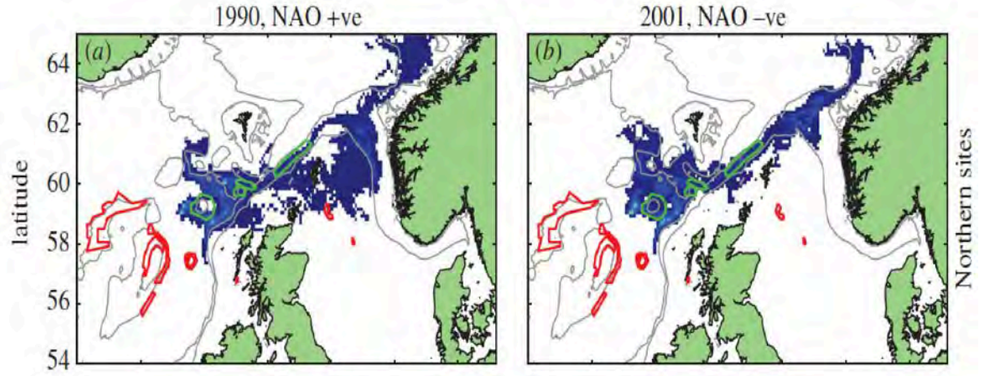
Biodiversity Loss

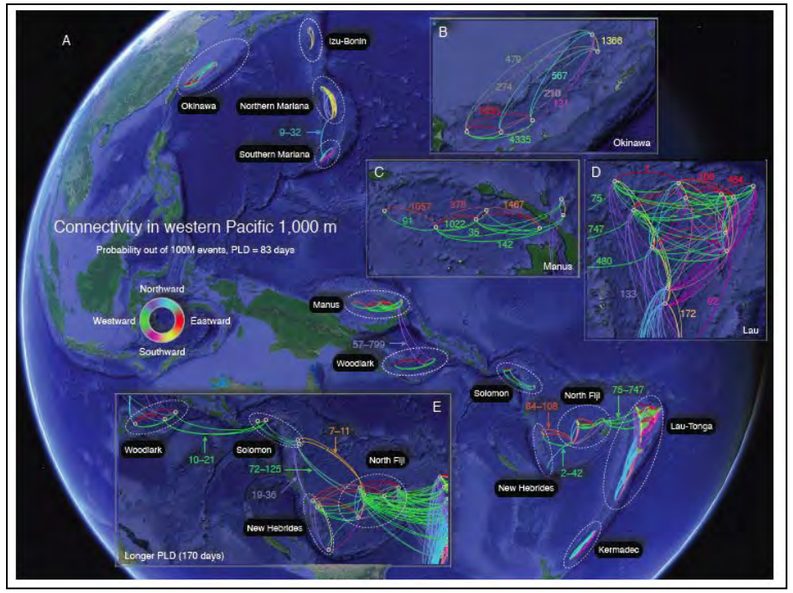


Cheung et al. 2016

Connectivity of MPAs

Fox et al. 2016





Mitarai et al 2016, PNAS

A role for climate in ‘BBNJ’

Biodiversity Beyond National Jurisdiction

Development of an international legally binding instrument under the United Nations Convention on the Law of the Sea on the **conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction**

Possible BBNJ elements:

I. Area-based management tools (including MPAs)

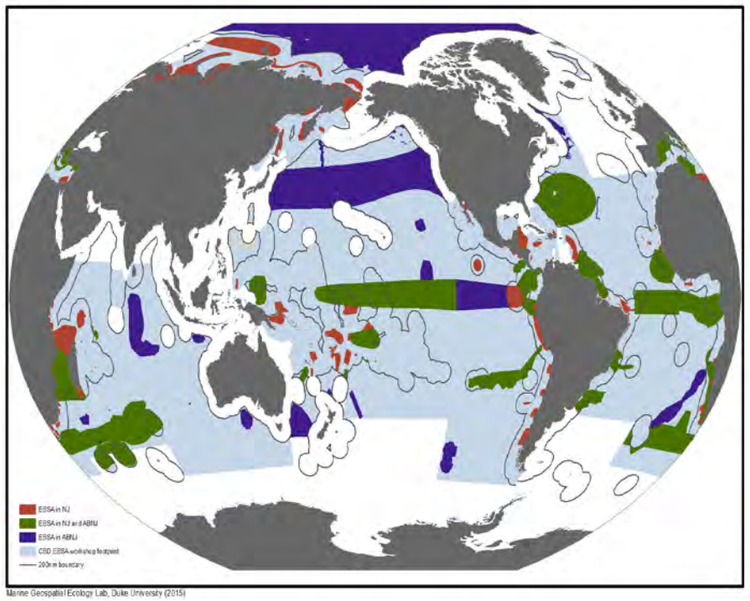
II. Environmental impact assessments

III. Marine genetic resources

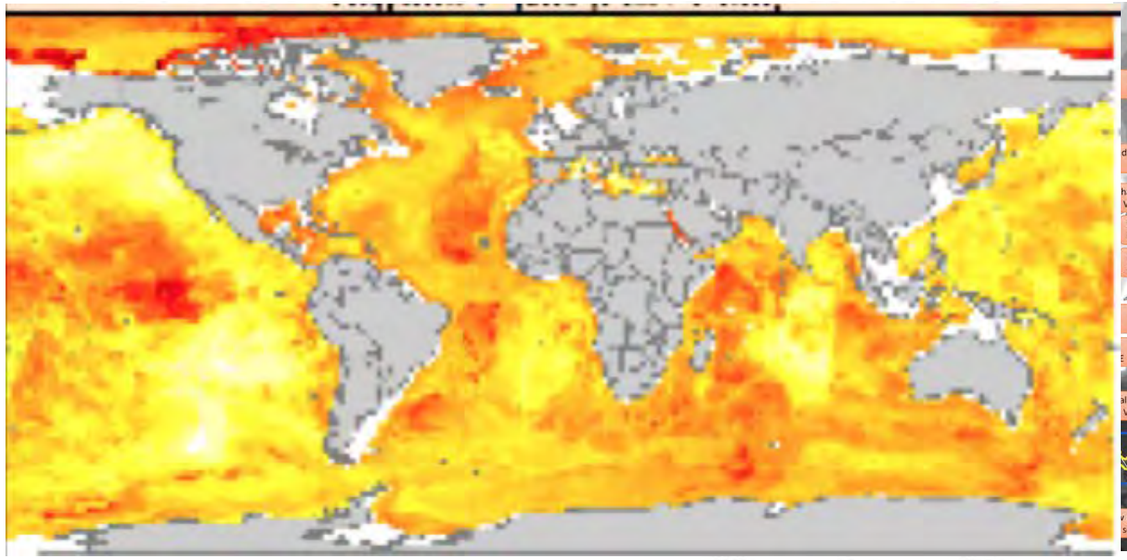
IV. Capacity building and the transfer of marine technology

Ecologically and Biologically Significant Areas

Convention on Biological Diversity

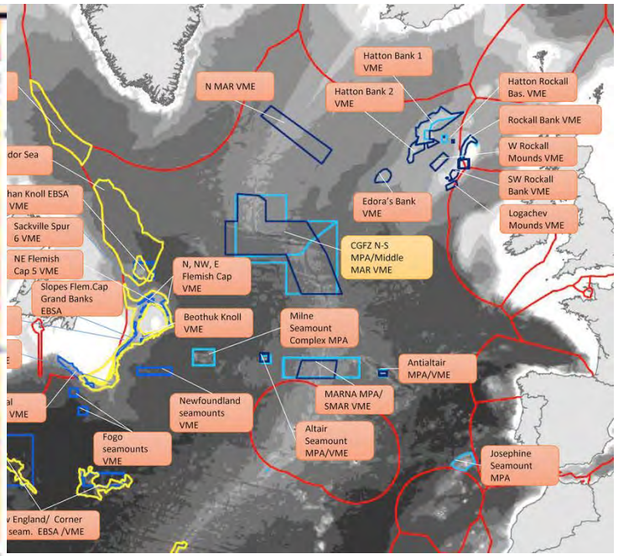


Cumulative Climate Impact



Ch8, Wei et al. in Deep-ocean climate change impacts on habitat, fish and fisheries. **FAO**

North Atlantic



Johnson et al. 2017

Climate and Environmental Impact Assessment

EIA Required

- Seabed mining (ISA)
- Deep sea fishing (FAO)
- Dumping of wastes + marine geoengineering research (IMO)

EIA Not Currently Required

Pelagic Fishing
Hydrocarbon extraction
Shipping discharge
Bioprospecting

BBNJ:

Ocean Energy
Aquaculture
Cables and Pipelines
Tourism

BASELINE STUDIES & MONITORING:

*measure climate variables (T, S, O2, Carbonate System, POC flux)
*vulnerabilities to climate

TRIGGERS AND THRESHOLDS for carrying out EIAs/SEAs ; decision making, serious harm

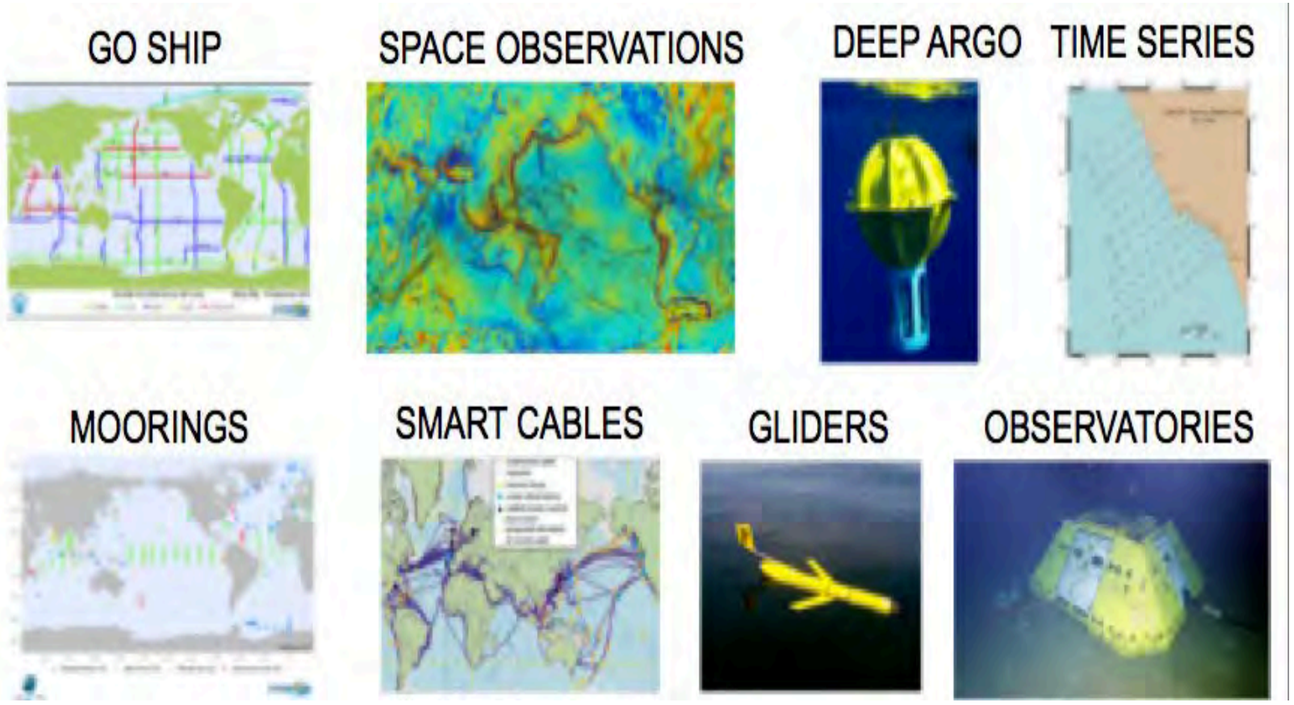
CUMULATIVE EFFECTS of targeted activity with climate-induced changes
(in combination with contaminants, particles, biota, microbes)

IMPACTS ON ECOSYSTEM SERVICES
made more vulnerable to physical disturbance by climate change

Can we put our observing programs to work to help incorporate climate into ecosystem-based management of the deep ocean?

- **New deep-ocean observations, technologies & coordination**

WHAT?? WHERE?? WHEN??



Application of genomics to impact and climate change assessment?

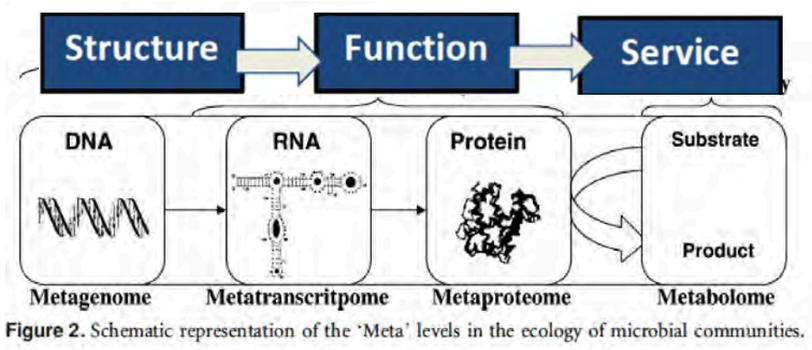
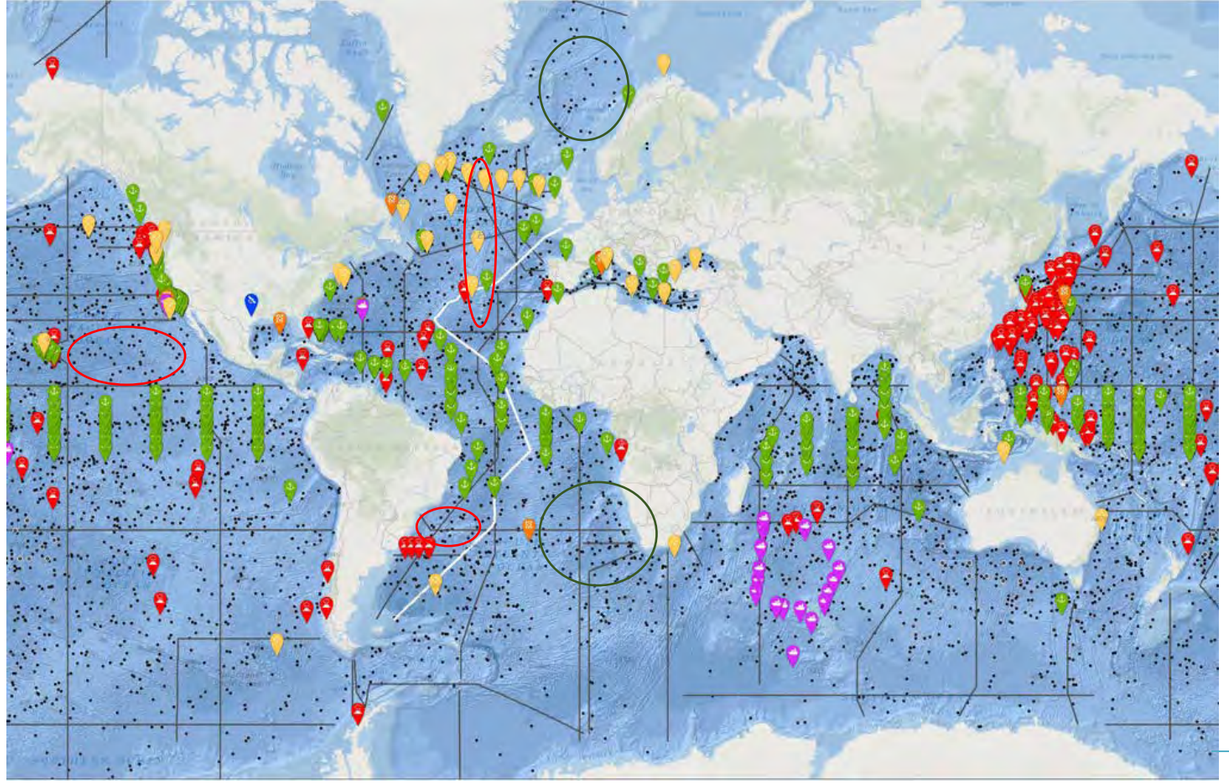


Figure 2. Schematic representation of the 'Meta' levels in the ecology of microbial communities.

Maron et al. 2007

DEEP OCEAN OBSERVING STRATEGY



Inventory of Sustained Deep-Ocean Observing

Integrate climate observing into ecosystem-based management of the deep ocean

DEEP OCEAN OBSERVING STRATEGY

www.deepoceanobserving.org

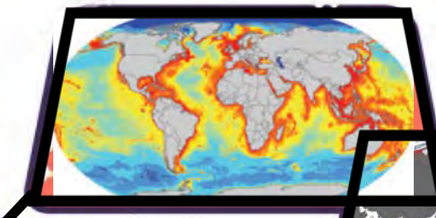
Essential Ocean Variables (for the Deep)

PHYSICS	BIOGEOCHEMISTRY	BIOLOGY AND ECOSYSTEMS
Sea state	**Oxygen**	Phytoplankton biomass and diversity
Ocean surface stress	Nutrients	Zooplankton biomass and diversity
Sea ice	Inorganic carbon	Fish abundance and distribution
Sea surface height	Transient tracers	Marine turtles, birds, mammals abundance and distribution
Sea surface temperature	Particulate matter	Live coral
Subsurface temperature	Nitrous oxide	Seagrass cover
Surface currents	Stable carbon isotopes	Macroalgal canopy
Subsurface currents	Dissolved organic carbon	Mangrove cover
Sea surface salinity	Ocean colour *(Spec Sheet under development)*	Microbe biomass and diversity (*emerging)
Subsurface salinity		Benthic invertebrate abundance and distribution (*emerging)
Ocean surface heat flux		

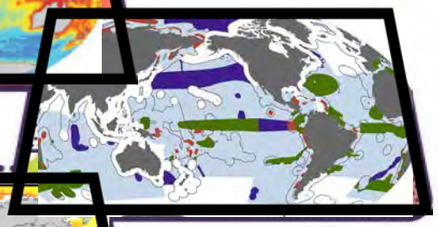
CLIMATE - HUMAN - POLICY CONNECTIONS

Putting our knowledge to work

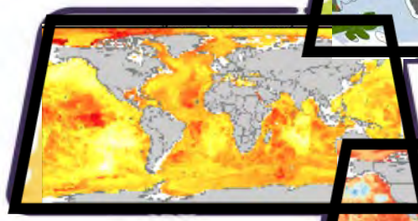
To enable sustainability in the deep ocean



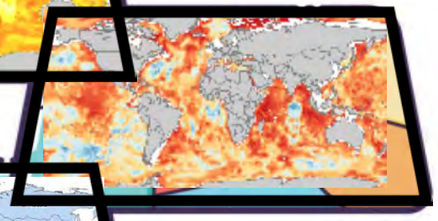
Biodiversity



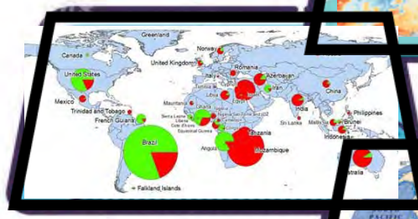
EBSAs/VMEs



Cumulative Climate Hazards

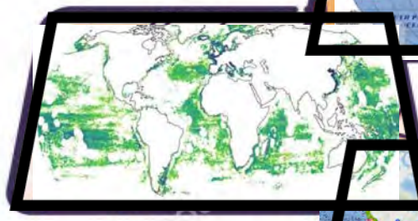


CC Time of Emergence



Offshore Oil and Gas

Seabed Mining



Fishing Activity/Bycatch

Deep-Ocean Observing

SUSTAINABLE DEVELOPMENT GOALS

17 GOALS TO TRANSFORM OUR WORLD

Inform Sustainability:

- Where to make new deep ocean observations.
- Essential ocean variables for deep-sea sustainability
- Effective spatial planning in the deep ocean
- Improved Environmental Impact Assessment
- New research directions

UNFCCC

Intergovernmental Oceanographic Commission

UNESCO

INTERNATIONAL SEABED AUTHORITY

FAO FIAT PANIS

CBD

UNEP

The Global Ocean Observing System GOOS

BBNJ

A new role for deep-sea scientists

SCIENCE DIPLOMACY

SCIENCE

International network for scientific investigations of deep-sea ecosystems

www.indeep-project.org

HUMANS

www.dosi-project.org

OBSERVING/ EXPLORATION

DEEP OCEAN OBSERVING STRATEGY

www.deepoceanobserving.org

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