# Marine Ecosystem Health

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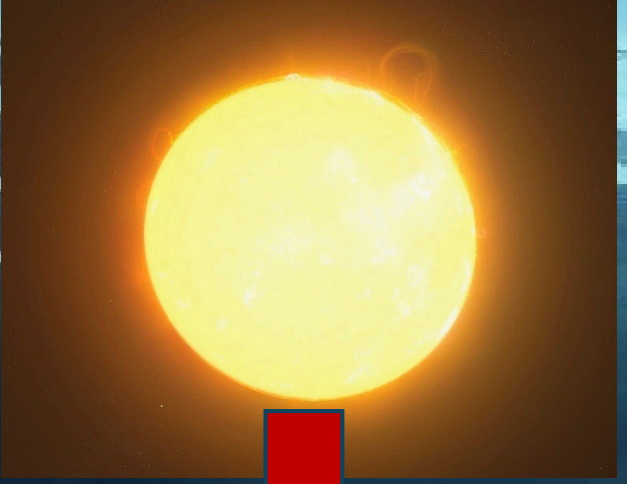


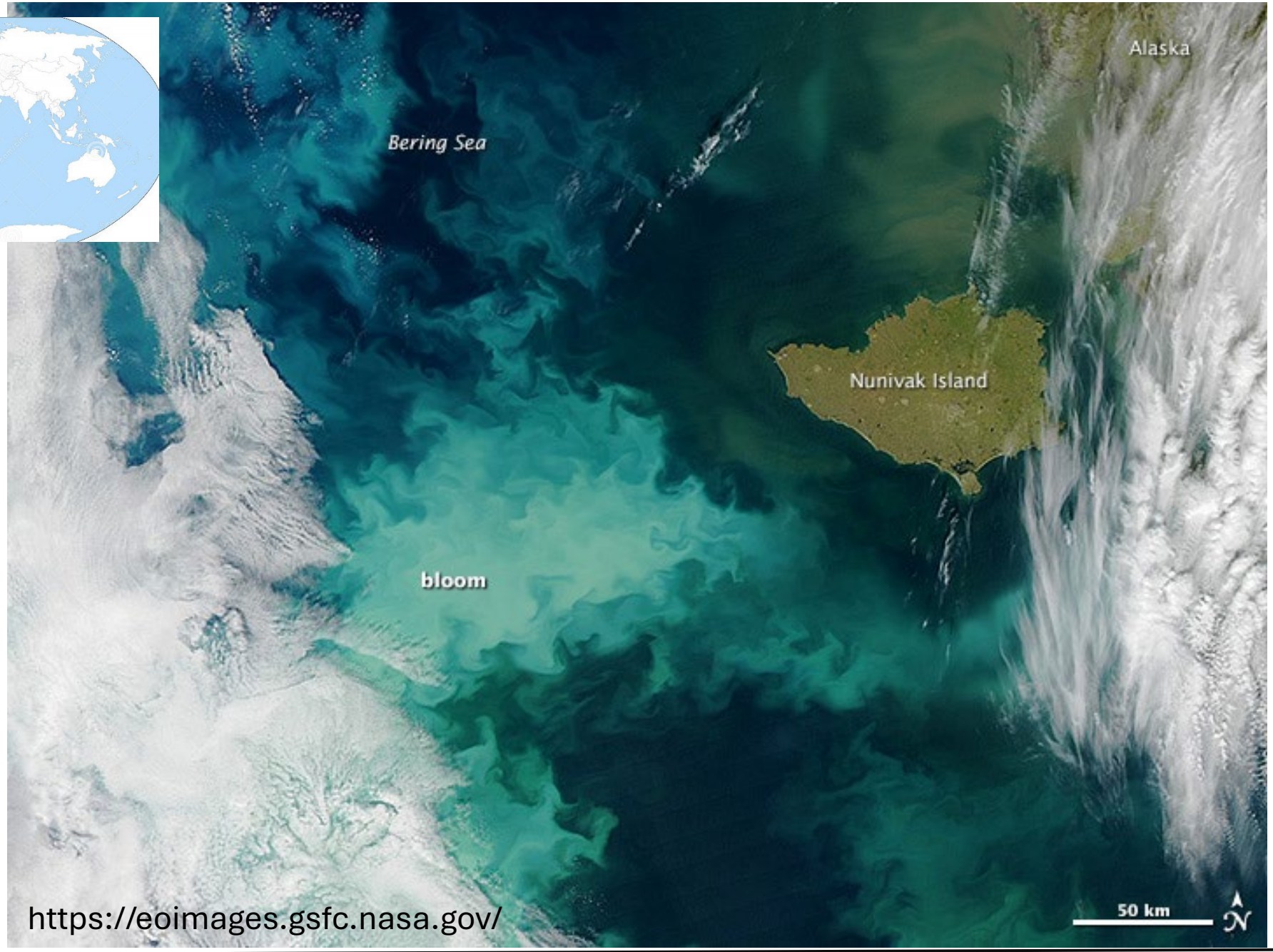


# marine ecosystem



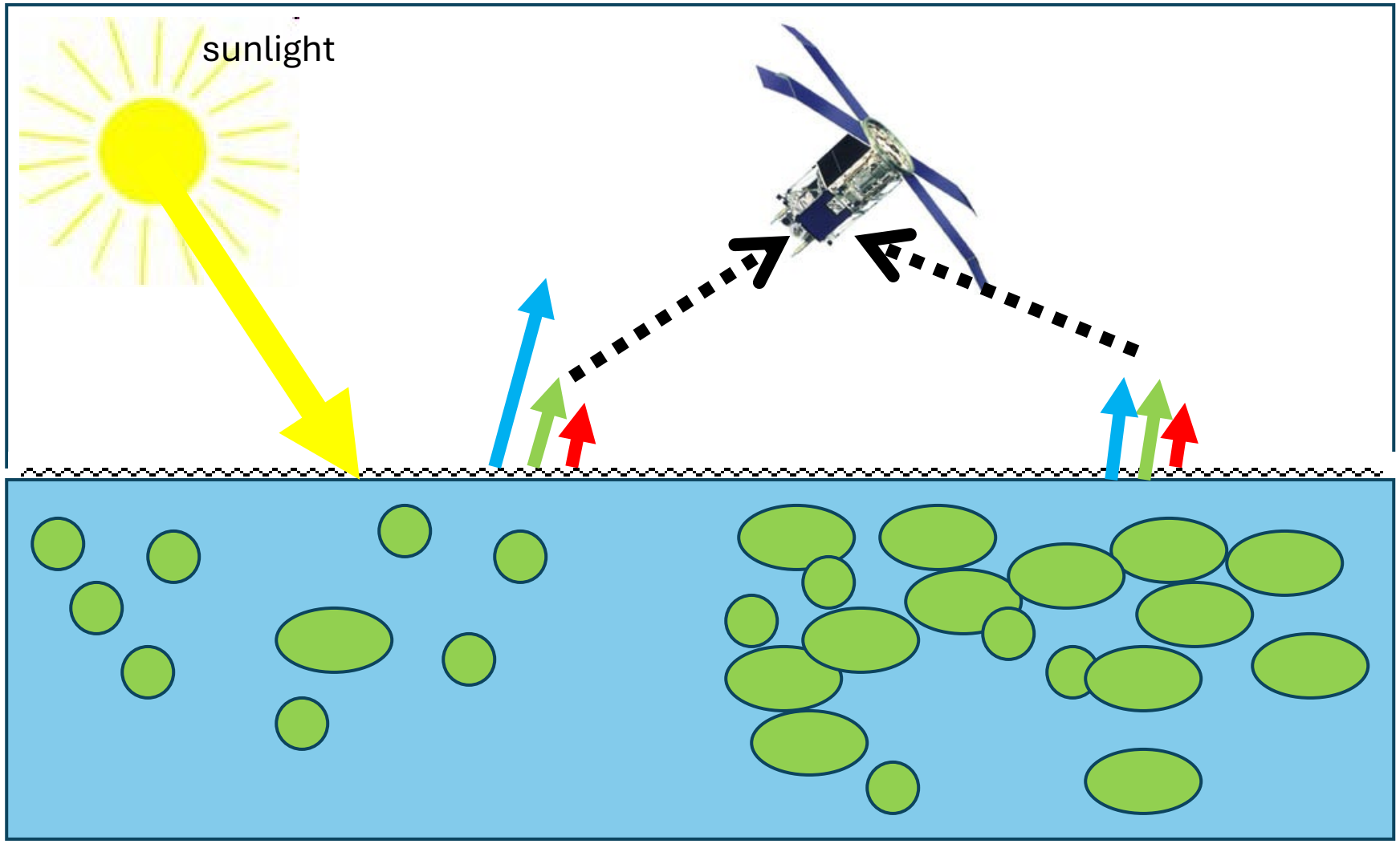

Center for Sustainability Science and Strategy

MODIS satellite, NASA




https://eoimages.gsfc.nasa.gov/

# monitoring plankton from ocean color satellites



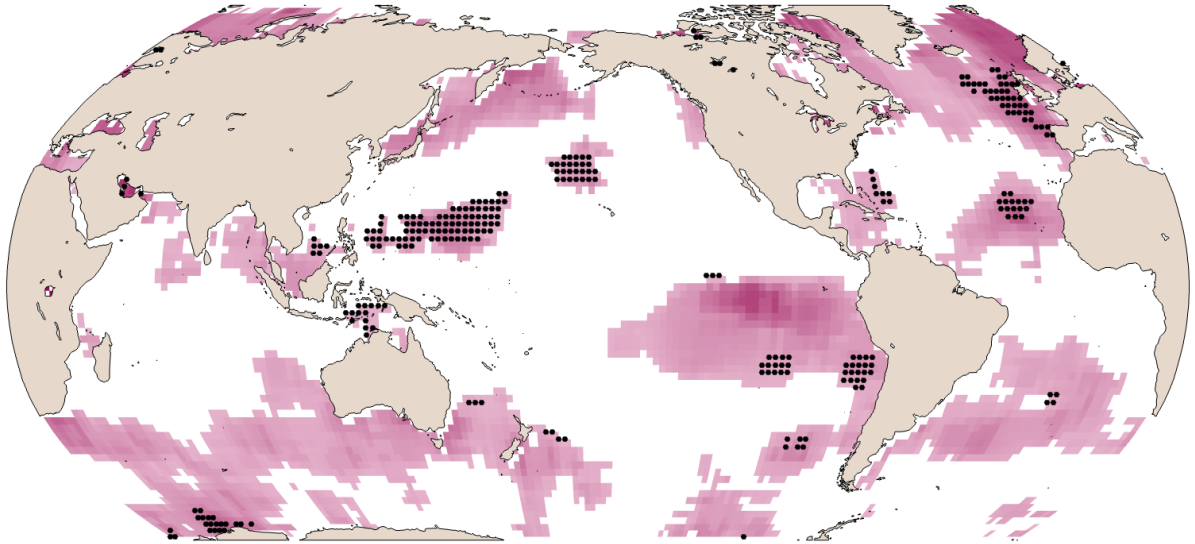
# Satellite-derived upper ocean Chl-a concentration (mg Chl/$m^3$)

Movie of global ocean Chl from

*Credit: https://svs.gsfc.nasa.gov/30754*

# MODIS satellite detected changes in Ocean Color (2002-2022): when using multivariate trend detection

42% ocean shows significant change in color




Signal-to-Noise ratio

Stippling indicates Chl-a trend SN>2

Color of ocean is changing

- Plankton populations have been changing

*Cael, Bisson, Boss, Dutkiewicz, Henson, Nature, 2023*

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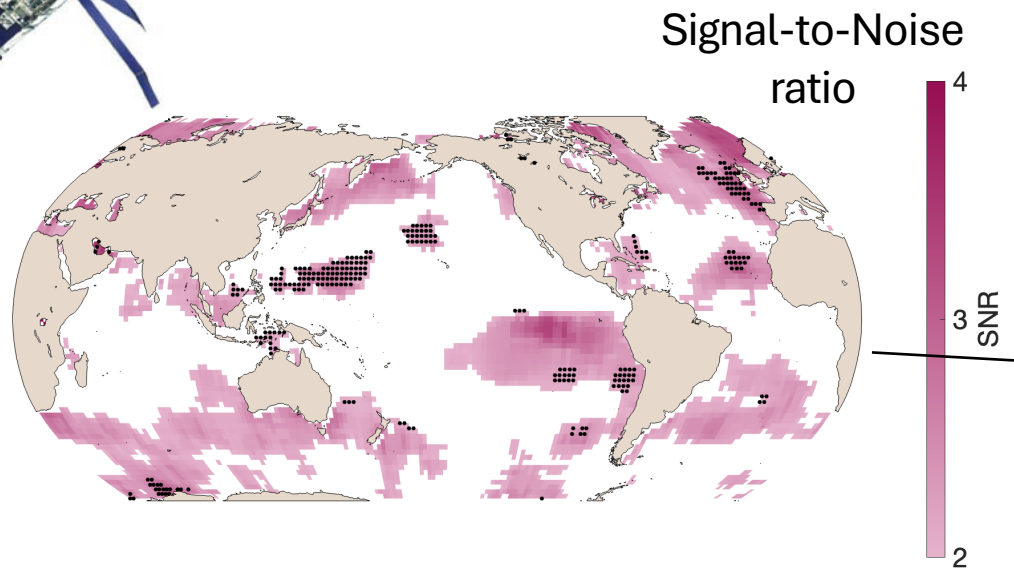
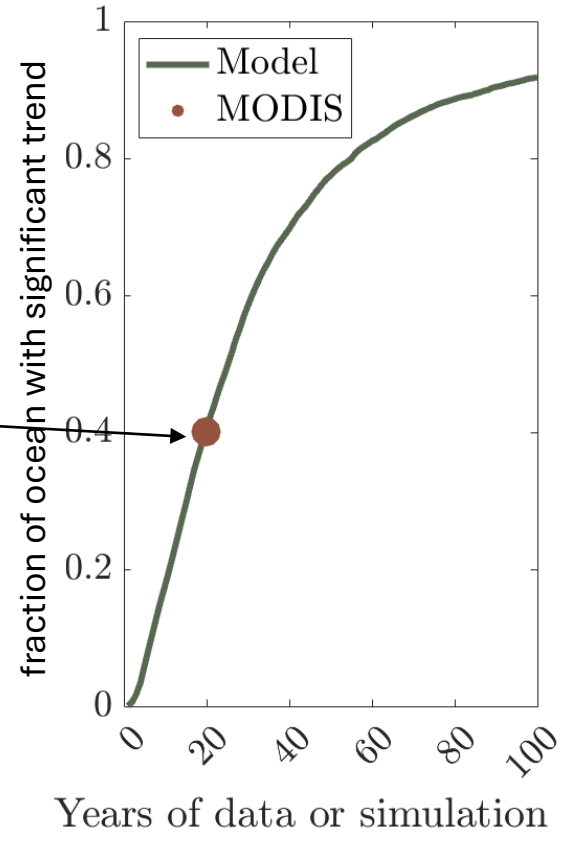



Computer symbol

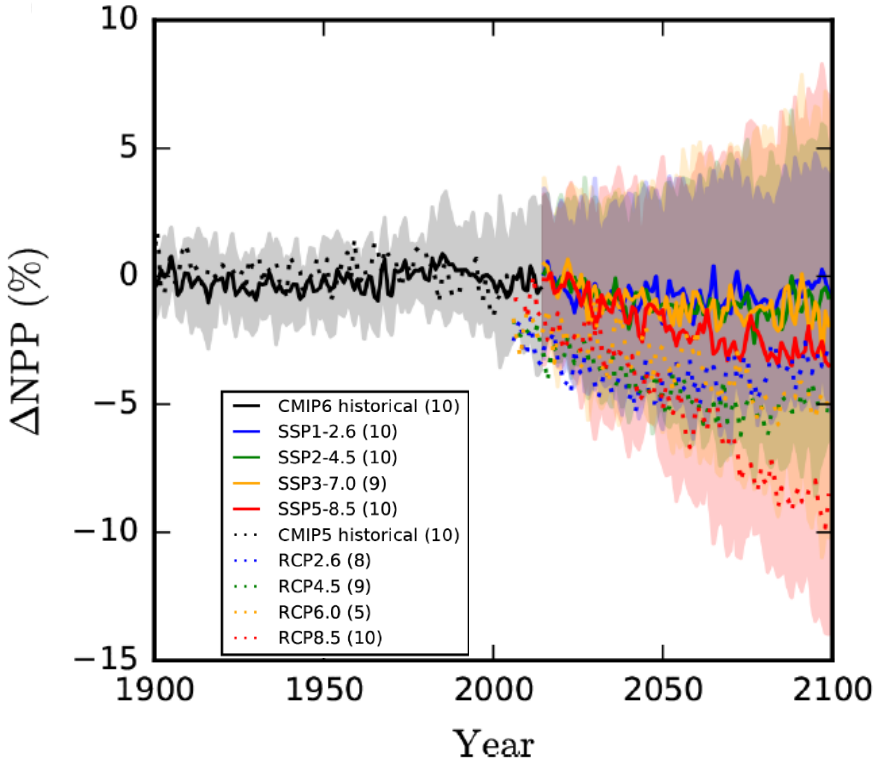
Color of ocean is changing

- Plankton populations have been changing
- Consistent with modelled climate-change driven alterations

*Cael, Bisson, Boss, Dutkiewicz, Henson, Nature, 2023*

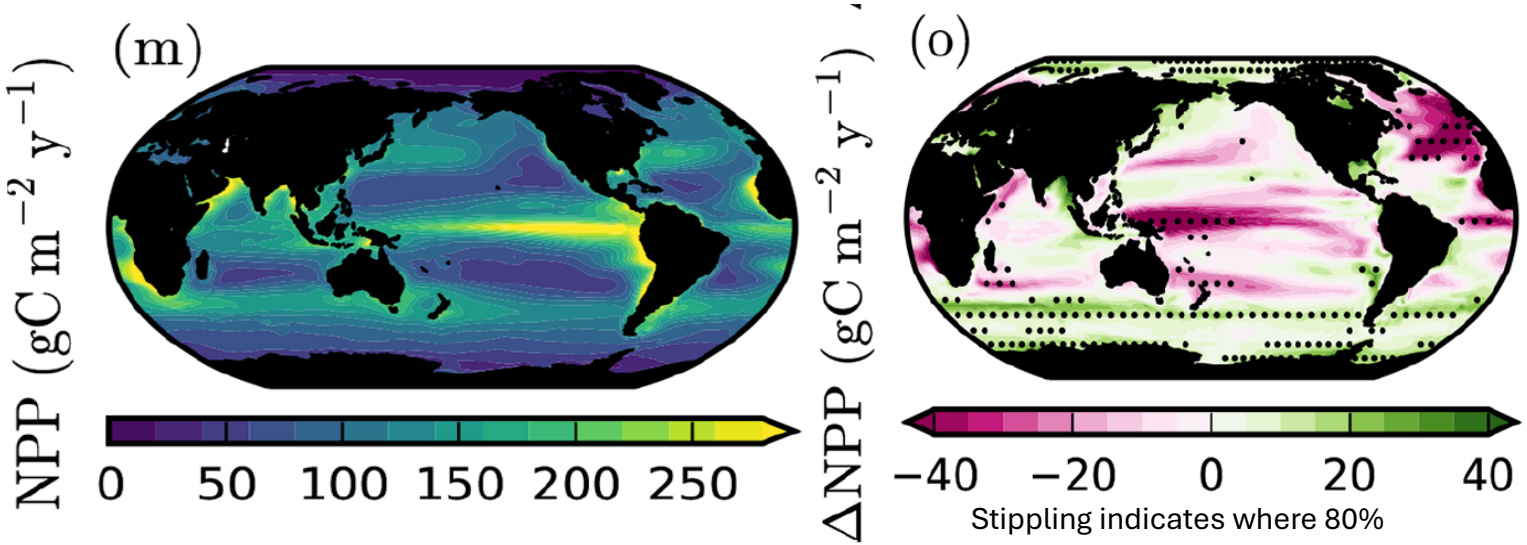
# Climate-change driven alteration to the phytoplankton

## Projected Change in Net Primary Production




Results average over 13 Earth System Models as part of the IPCC Coupled Model Intercomparison Project (CMIP6)

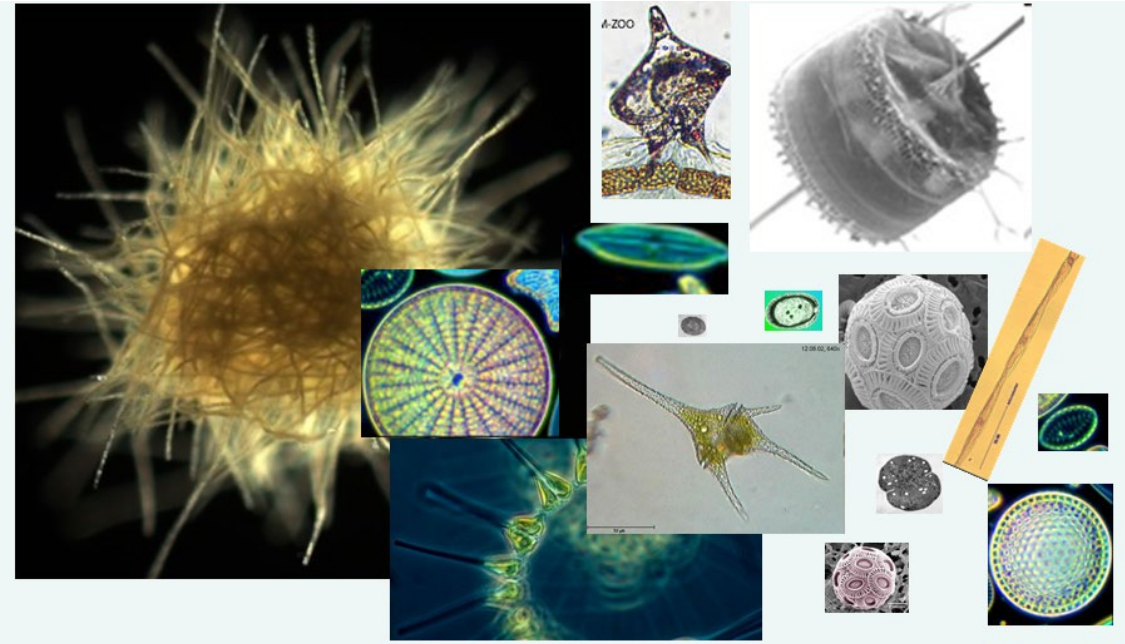
*Kwiatkowski et al, Biogeosciences 2020*




Productivity of ocean predicted to change regionally – some increases, some decreases

- Caused by warming, reduced nutrient supply, alterations in light fields

# Climate-change driven alteration to the phytoplankton



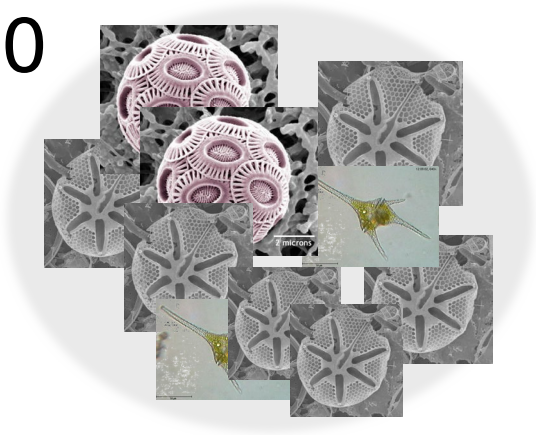

Phytoplankton are very diverse:

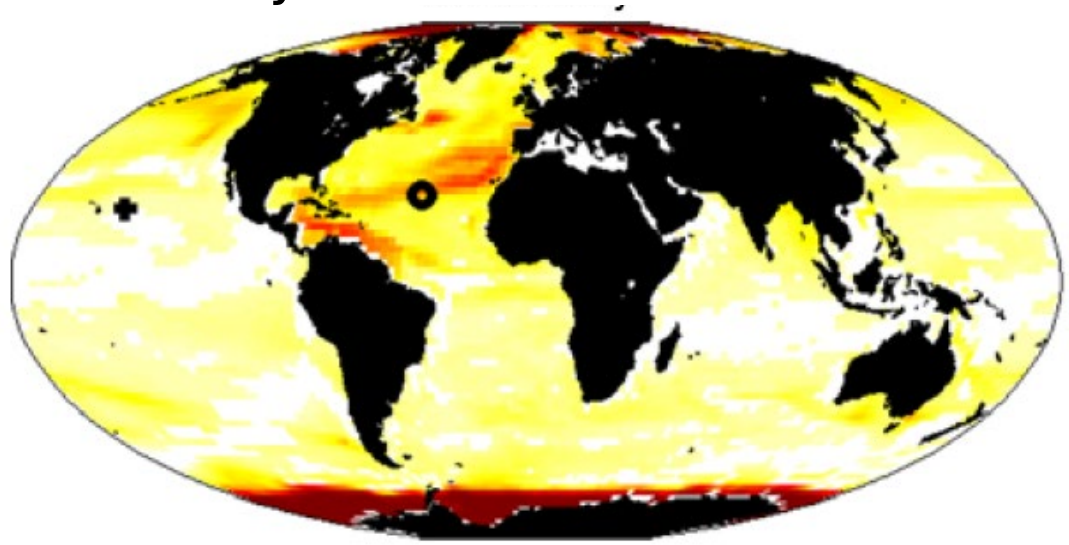
- 10,000s of species
- differ in size, shade, nutrition

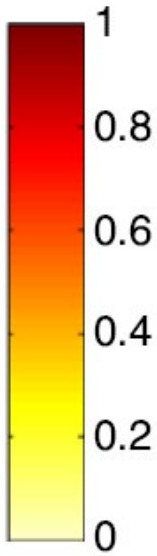
# Climate-change driven alteration to the phytoplankton

Model prediction of how dissimilar community is in 2100 relative to 2000

2000



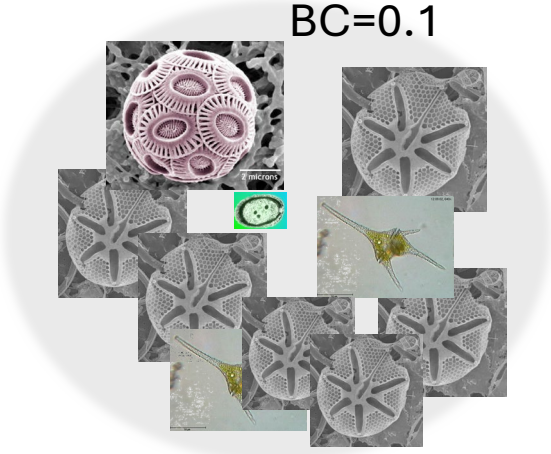




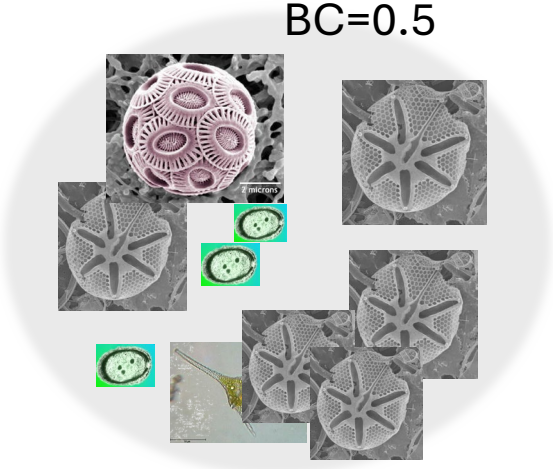

Brey-Curtis Dissimilarity Index

2100

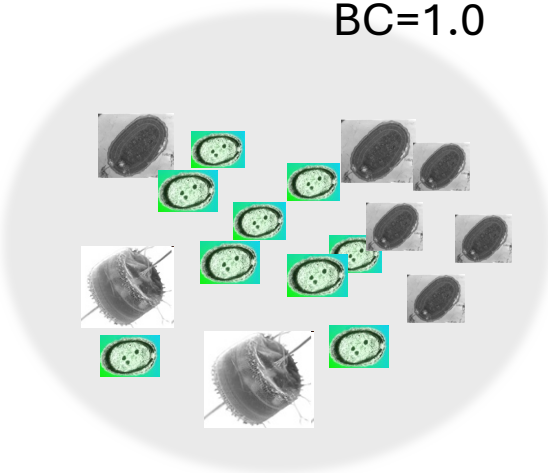
BC=0.1



BC=0.5



BC=1.0



# Climate-change driven alteration to the phytoplankton

- Color of ocean is changing
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What does this mean for the “health” of the marine ecosystem?

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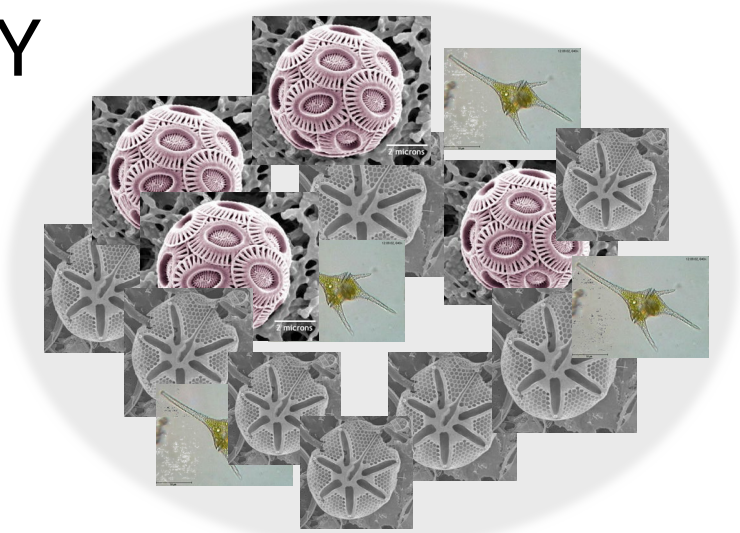
- Changes at bottom of food chain will cause complex alterations to higher trophic levels

TODAY



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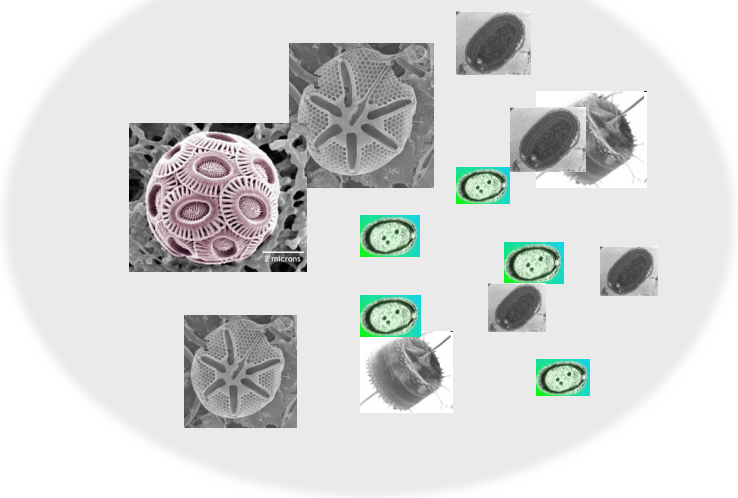

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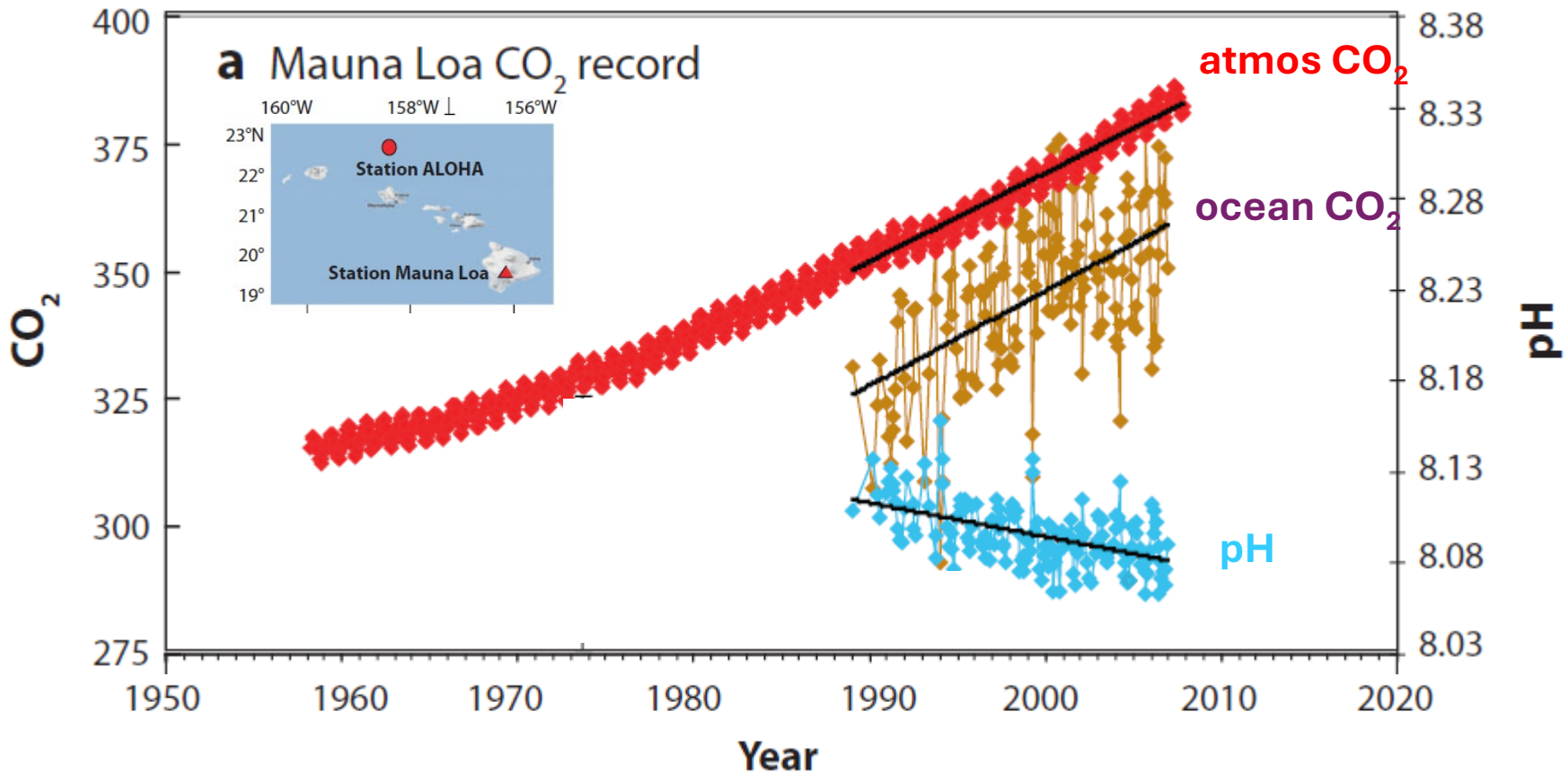
What does this mean for the “health” of the marine ecosystem?

- Changes at bottom of food chain will cause complex alterations to higher trophic levels
- Changes happening faster the higher trophic levels can adapt
- Stability of foodwebs threatened

# What are other changes that are occurring that are affecting the ecosystems health?

- Ocean acidification
- De-oxygenation
- Pollution: plastics, mercury, other toxic substances
- Overfishing

# Ocean Acidification



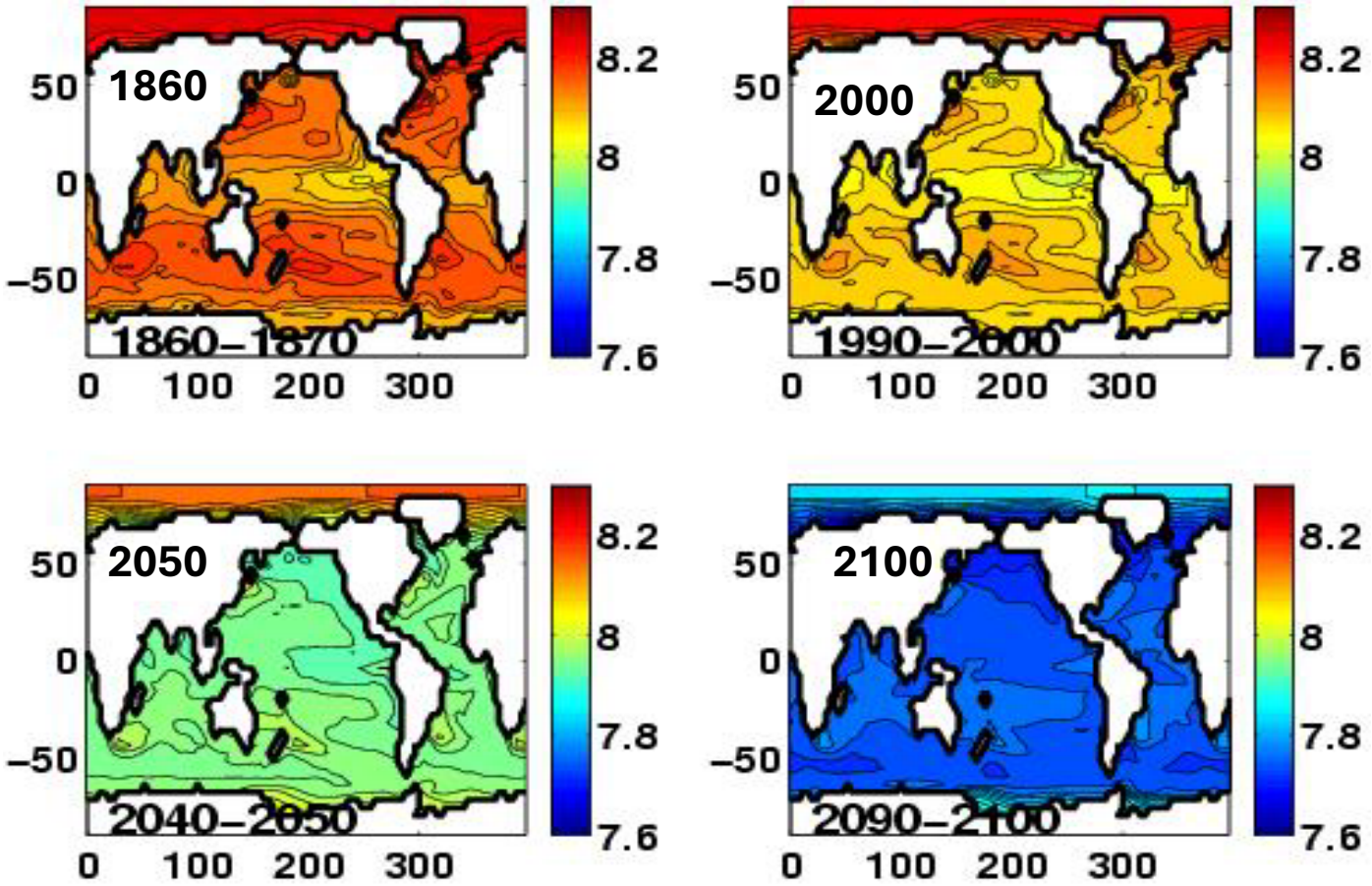

- Ocean has absorbed about 1/3 anthropogenic $CO_2$
- Higher carbon leads to increased in acidity (lower pH)

*Doney et al, Ann Rev Mar Sci, 2009*

# Ocean Acidification

Surface pH

alkaline>7
neutral=7
acidic<7



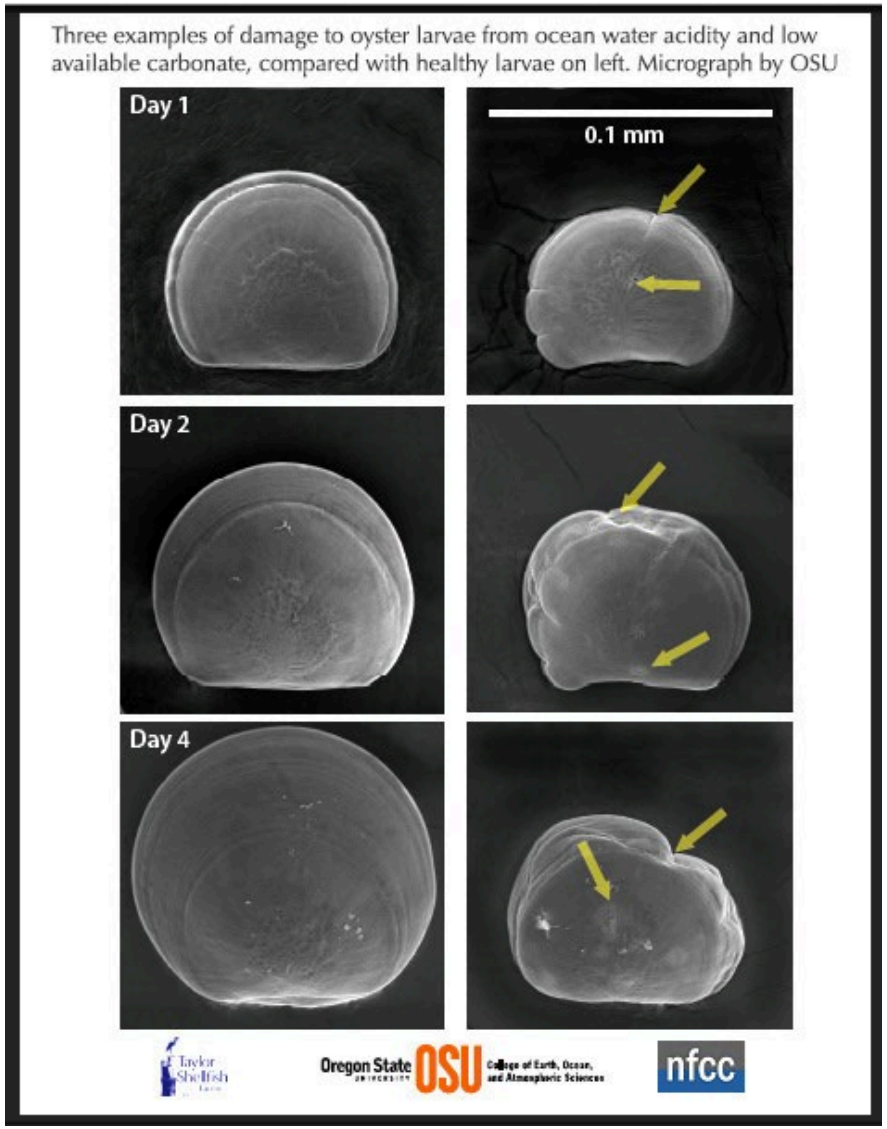

Model results under high emissions scenario

- Many organisms are adversely affected reduced pH

*Dutkiewicz et al, JP Report 122, 2005*

# Ocean Acidification

- Acidification affects bivalve larvae
- Impact on aquaculture
  (significant on US West coast)
- NOAA monitoring network



# Plastic Pollution

Photo: Chris Jordan

Photo: Wikimedia Commons

# Plastic Pollution

Zooplankton eating Phytoplankton

Zooplankton eating micro-plastics

movies

SloMo 1:20

SloMo 1:20

SloMo 1:15

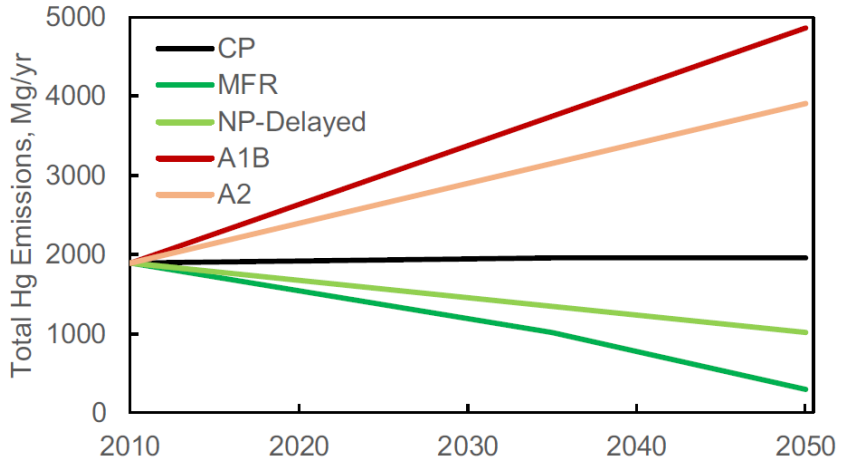
SloMo 1:15

*Gonçalves et al. MEPS 2014*

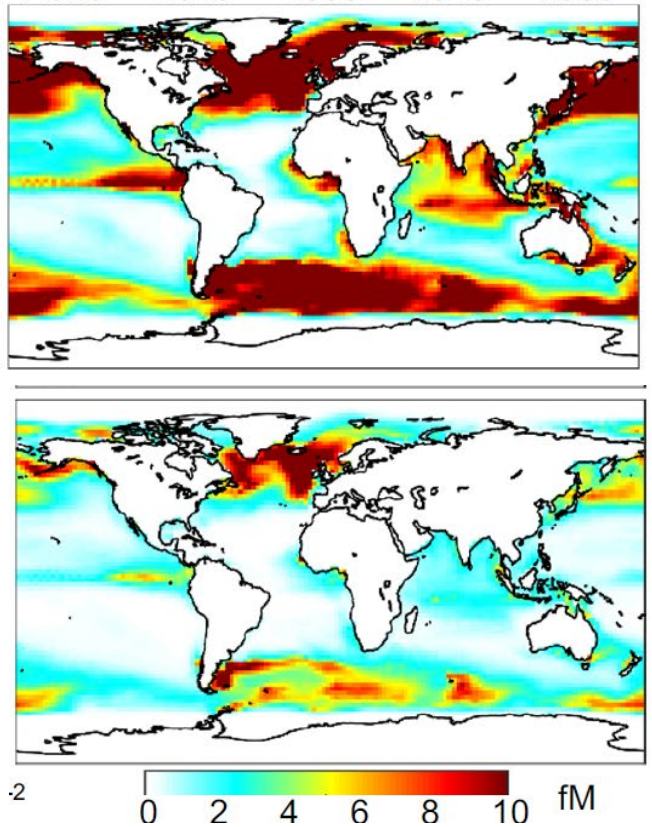
Movie credit: Thomas Kieorboe, DTU, Denmark

# Mercury Pollution

- Mercury bioaccumulates
- Larges magnification occurs between seawater and plankton
- Continues up marine food chain to fisheries
- Cause neurological damage to humans




Projected mercury in marine plankton by 2050 under different policy scenarios




no policy (A1B)

maximum feasible reduction (MFR)

*Zhang et al, Nature Communications, 2021*

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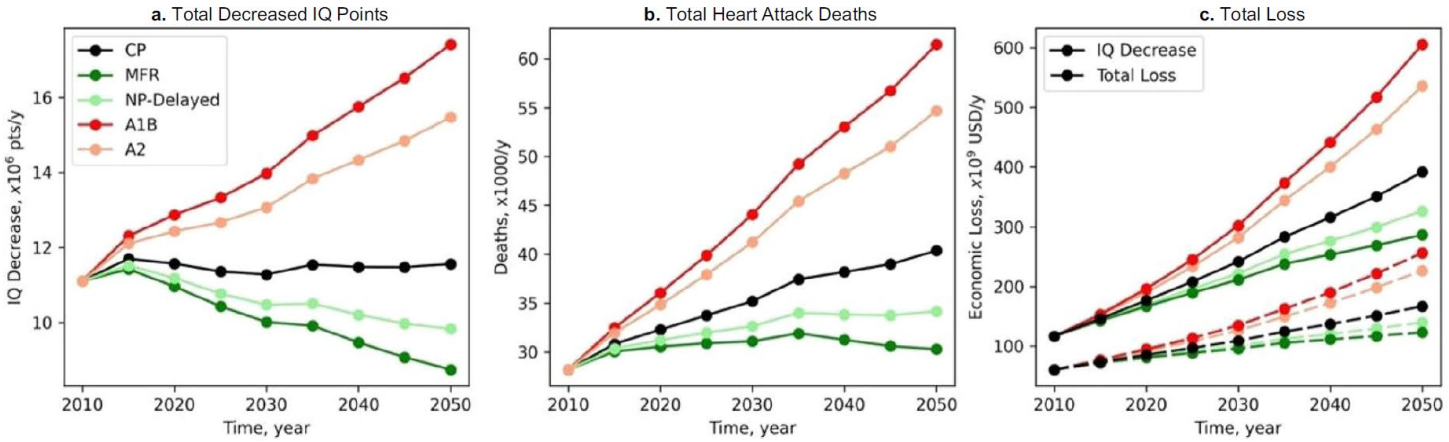


- Treaties such as the Miranmata Convention (2017) will lead to significant improvement in human health

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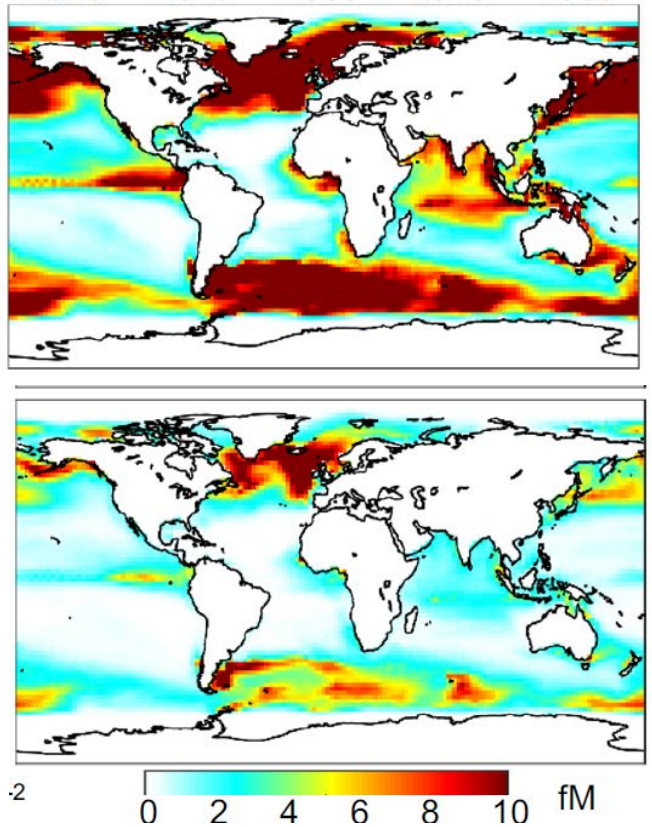


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- Evidence from satellites that almost half the ocean has had a perceptible change in color over the last 2 decades

- Such changes indicates an alteration in the phytoplankton at the base of the marine food web - both in abundance and community structure

- Organisms higher up the food chain will struggle to adapt to these rapid changes, likely leading to more ephemeral and less stable regional ecosystems

- Additional  issues impacting on the health of the ocean ecosystem include plastic and mercury pollution, de-oxygenation, over-fishing