Biodiversity Loss and Ecosystem Disruption

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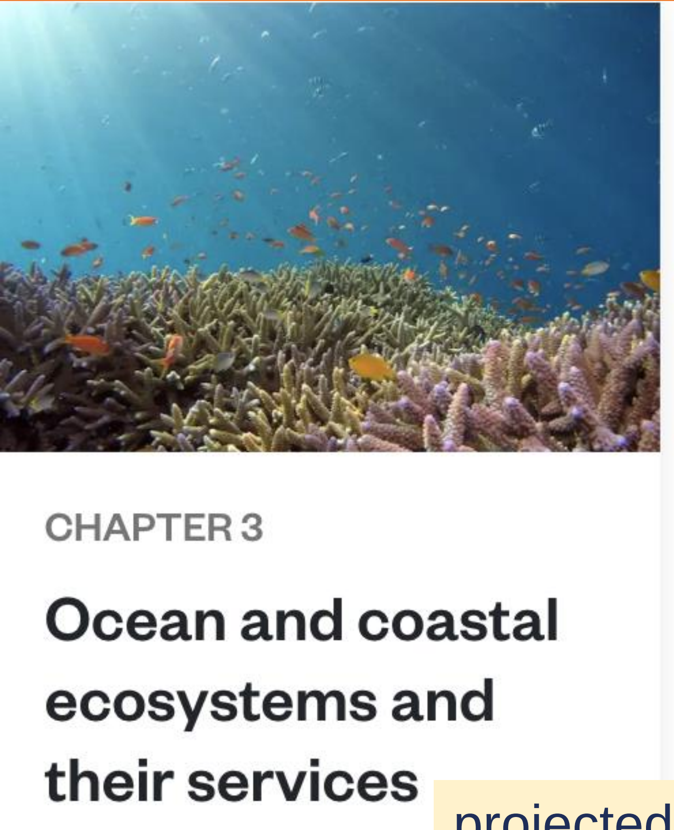
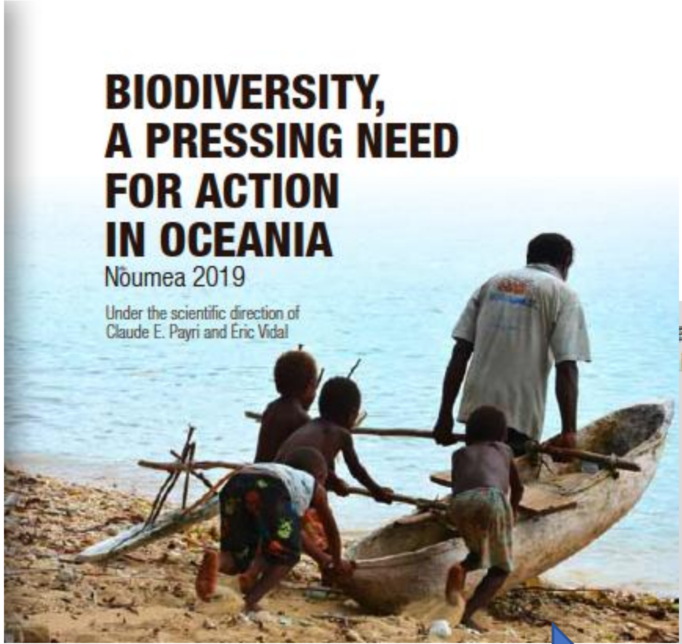
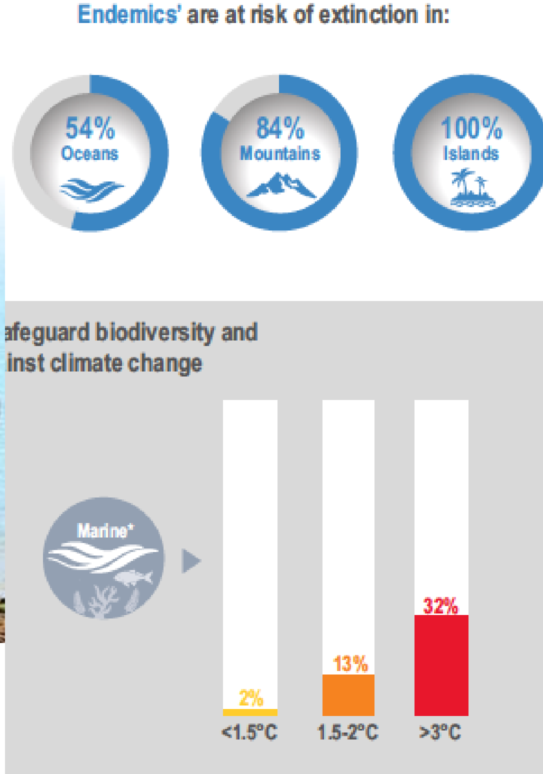
Linking IPCC to IPBES

Intergovernmental Panel on Climate change (IPCC)

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)





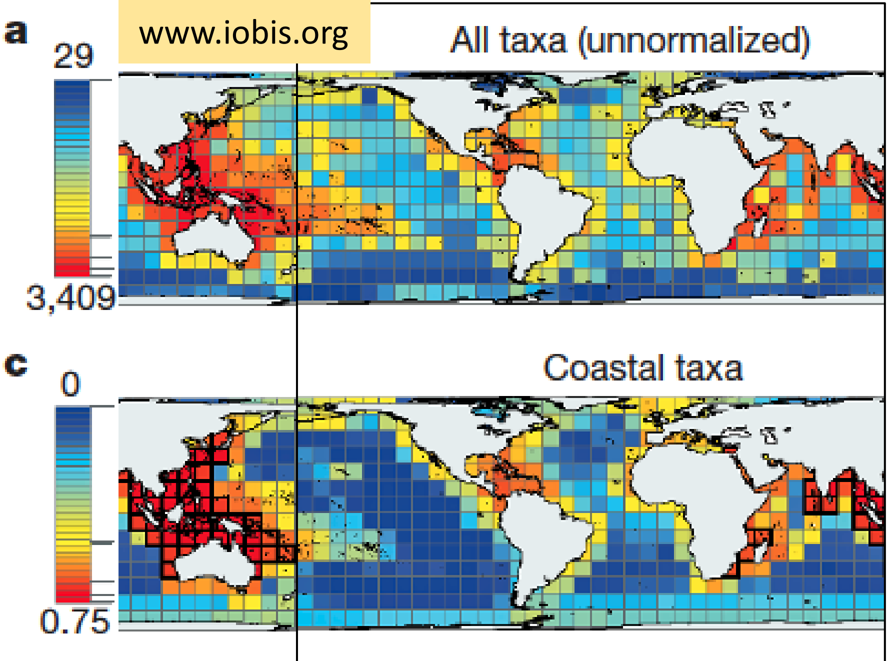


projected risks of species extinction at global warming levels

Outline of the presentation

1. Why are climate variations important for marine ecosystems: some basics
2. What are the main climate drivers that are most commonly used to look at biodiversity and fate of ecosystems
3. What are the projected future for diverse ecosystems
4. Climate change projected impact on coral population
5. Conclusions

- IBPES: the main direct cause of biodiversity loss is land use change (primarily for large-scale food production) which drives an estimated 30% of biodiversity decline globally. Second is over-exploitation (overfishing, overhunting and overharvesting)



- Oceania overall hosts the highest concentration of marine biodiversity

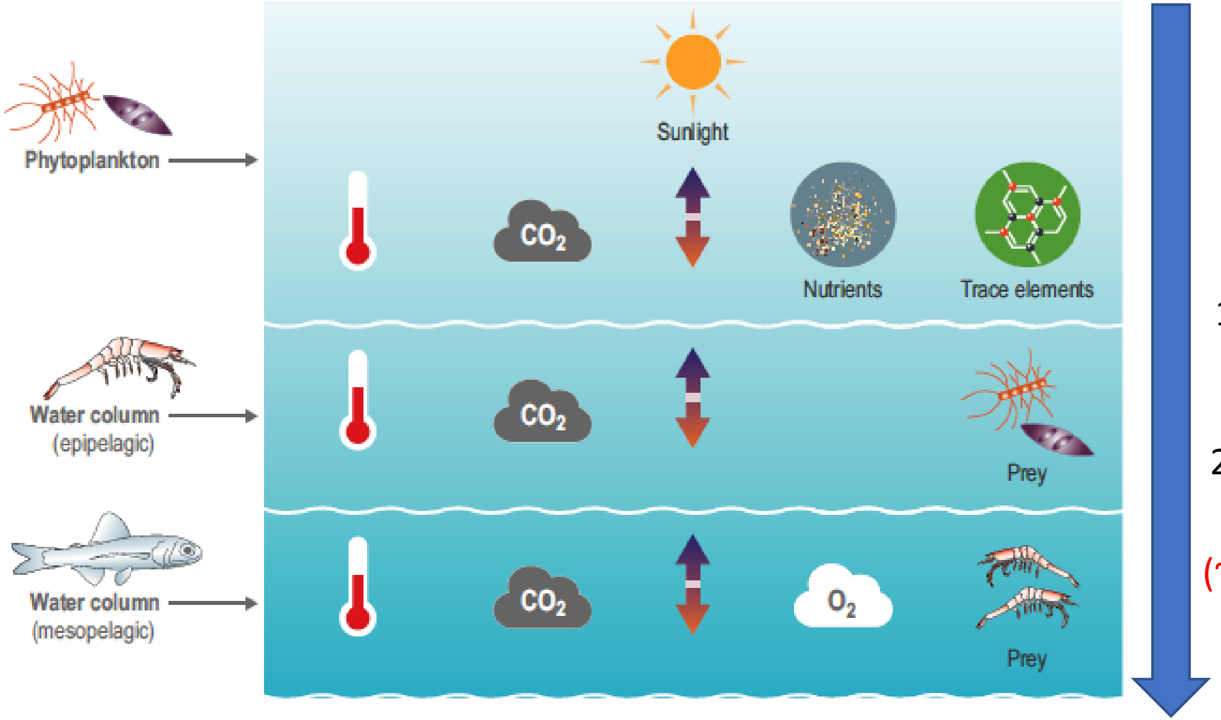
- Strong West-to-East biodiversity gradient

- IUCN (International Union for Conservation of Nature) 2018: up to 20% of marine species are threatened species

- 50% of Australia live coral barrier « disappeared » between 1985 and 2012 as a result of bleaching , cyclones, and Acanthaster (crowne of thorns) outbreaks. Additional 30% during the 2016 Marine Heat Wave on top of slow ocean warming: coral reef under extreme threat due to climate change and anthropic pressure.

- Subsistence fishing is estimated to be ~70% of coastal fish catch and exploited open ocean fishing is also

Basics: we usually consider typical layers in the ocean describing a range of physical properties and species



This top layer the euphotic layer. This is where food for trophic web is created by phytoplankton: Primary production

150m

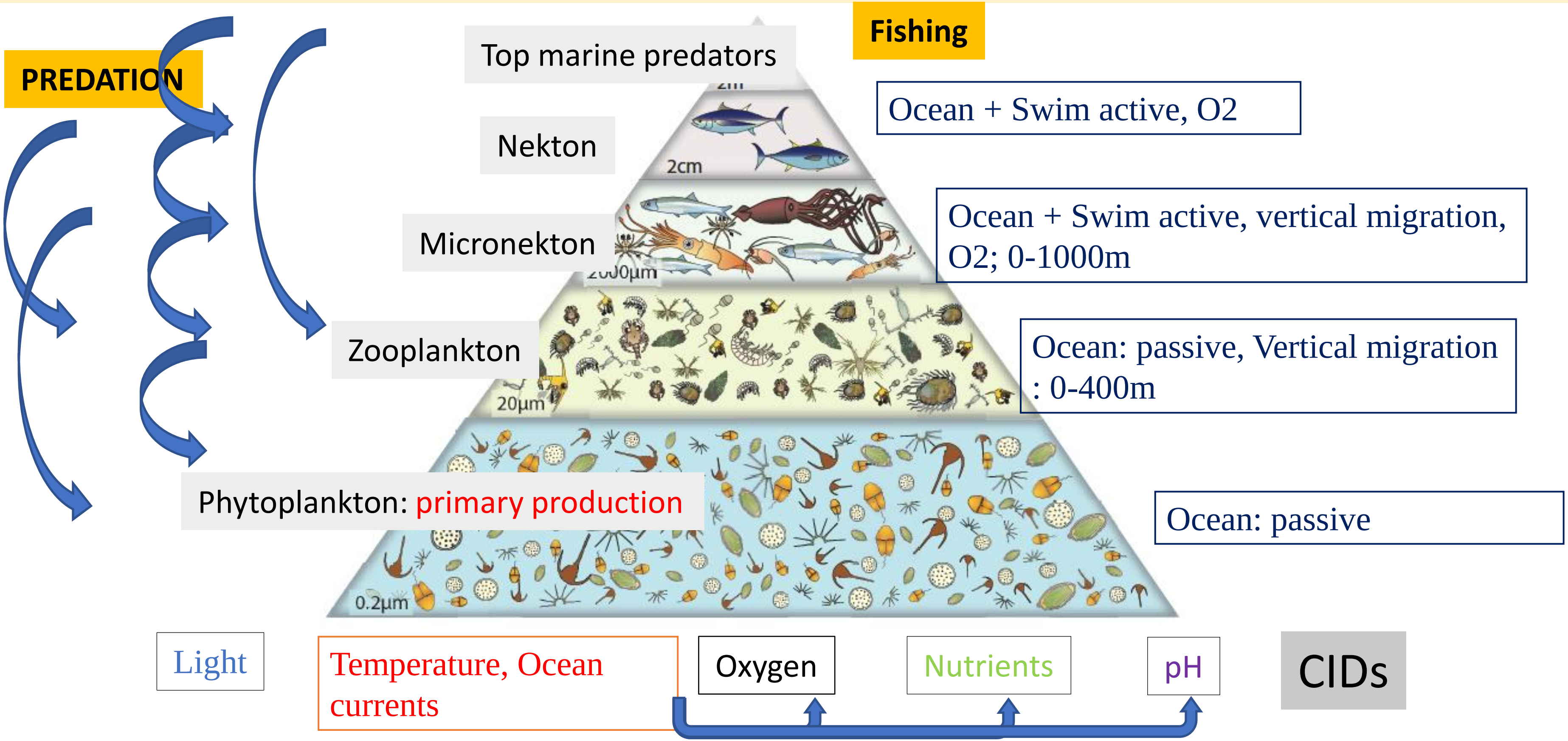
200m epipelagic layer ~ thermocline

(~below thermocline) mesopelagic layer

1000m

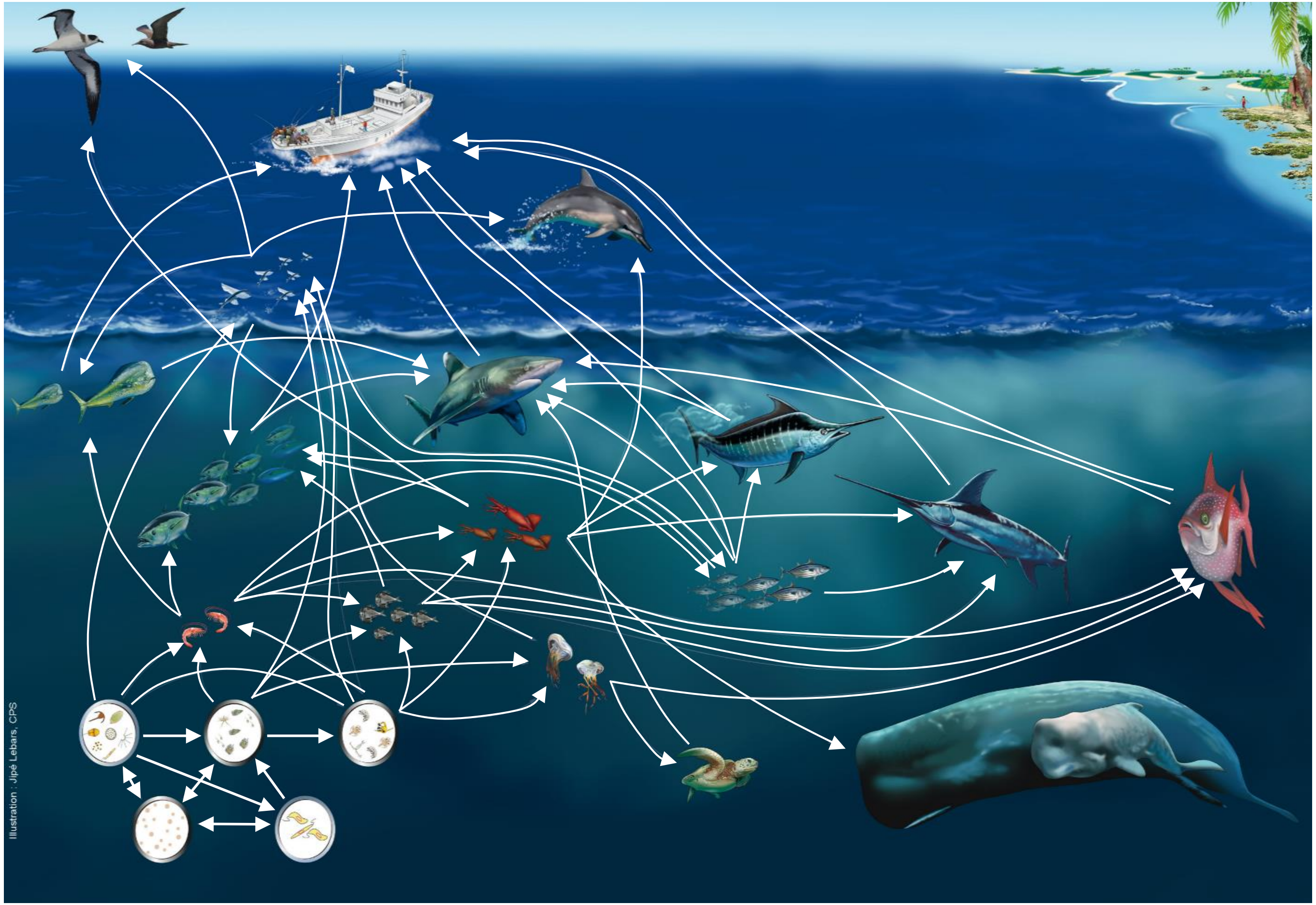
bathypelagic layer in open ocean

Climate Impact-Drivers (CID): Climate influences the food web at all trophic levels.



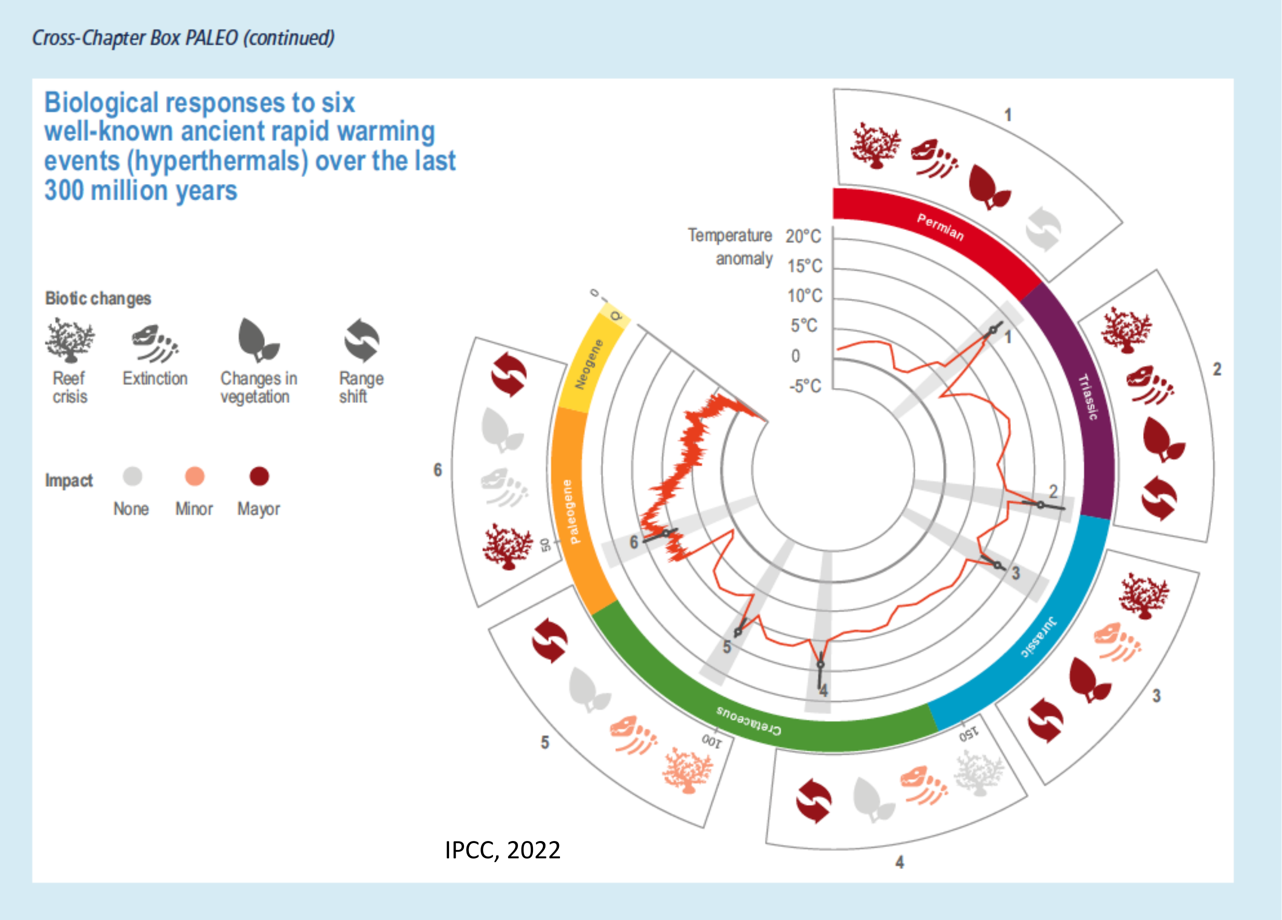
CLIMATE CHANGE influence : a complex combination of hydrodynamics, biogeochemistry and ecology. As a result uncertainties at each level add on

A much more complex albeit still very crude view of the ecosystem (open ocean…..



We can imagine that understanding the impact of climate change onto ecosystem in general will be very difficult…

Climate Impact-Drivers : ancient history proves climate can dramatically affect the ecosystems up to extinctions and/or profound structural changes.



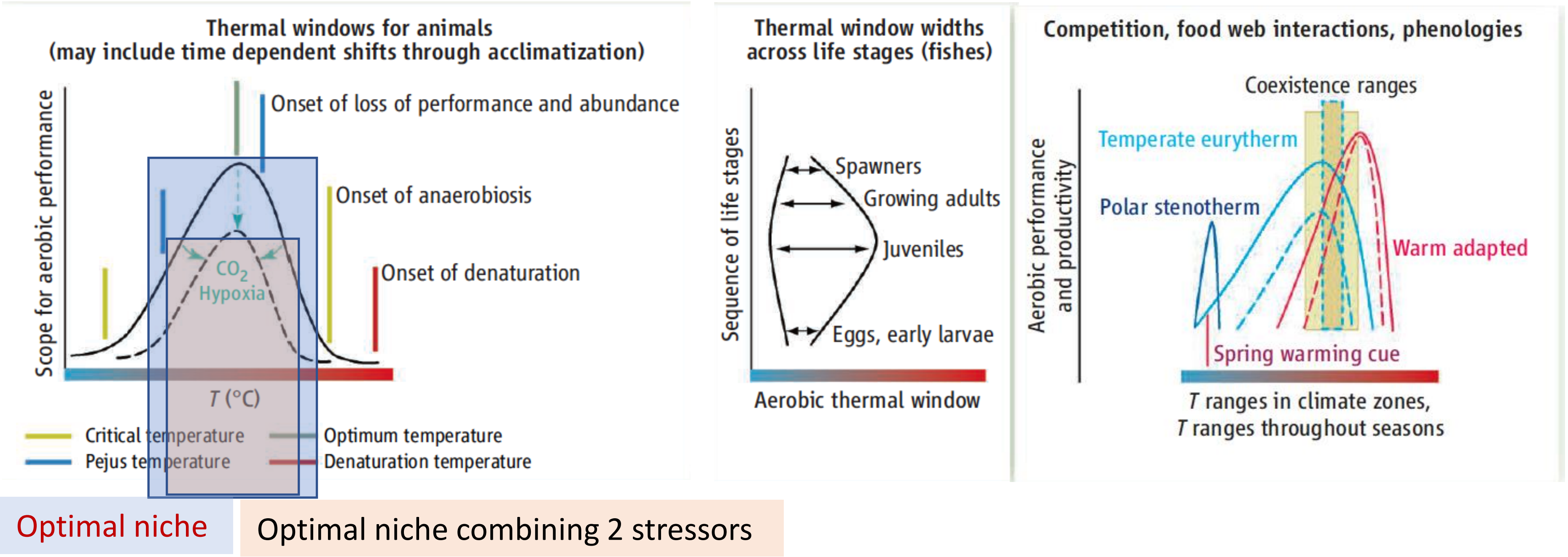
IPCC, 2022

Hyperthermal (higher temperature) events in the paleo records have been associated with higher CO2, lower pH, lower oxygen, and mass species extinctions up to 70%.

That is one of the current fear for the ecosystems

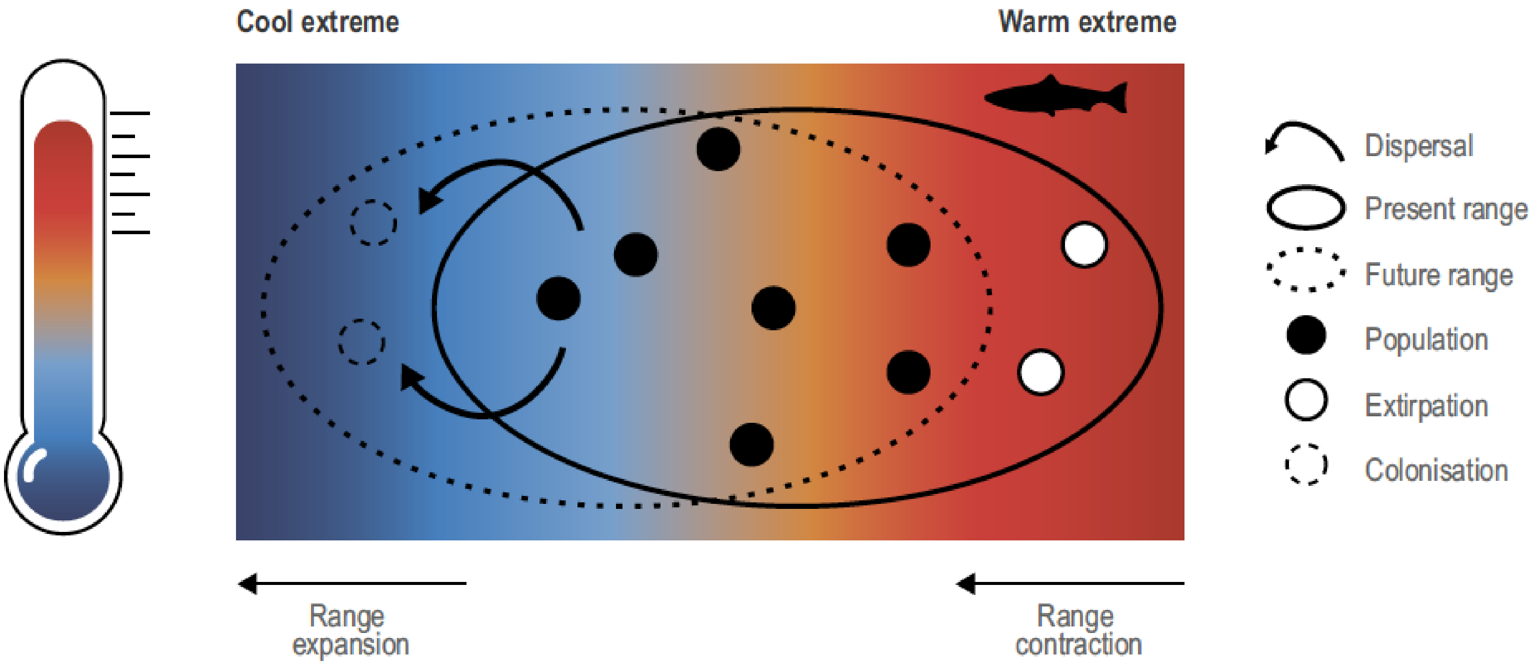
Some species however could survive

Temperature, a key variable for ecosystems that combines with other drivers: compound "Richard's" effect



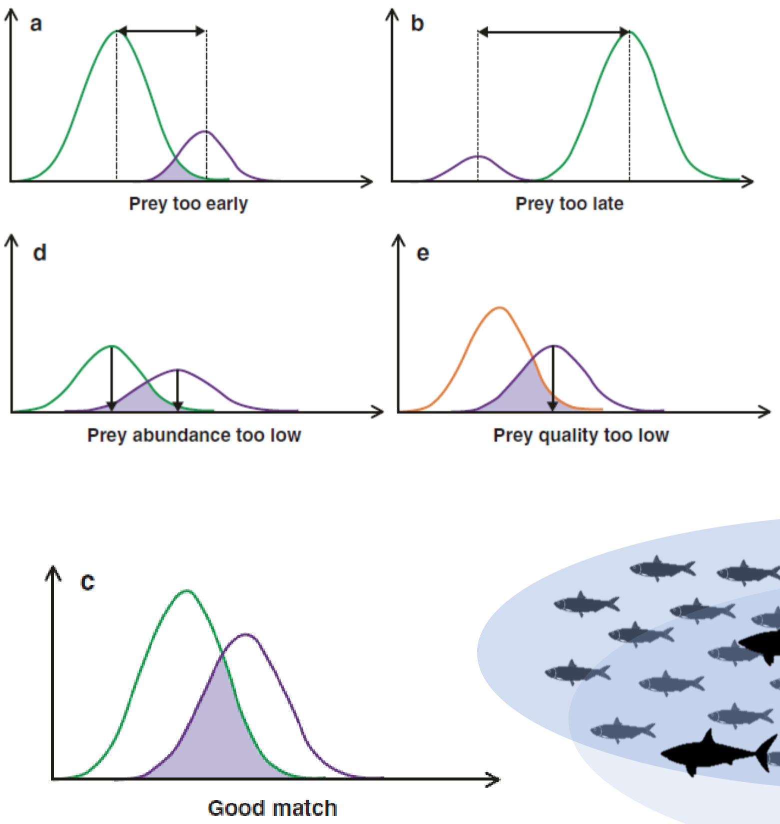
By altering physiological responses, projected changes in ocean warming modifies growth, migration, distribution, competition, survival and reproduction. It is rare to know how individual species respond to temperature changes for instance especially in the presence of other predators/preys. Hence a vast majority of studies overlay species observed distributions with temperature distributions to empirically derive temperature **"realized niche"**.

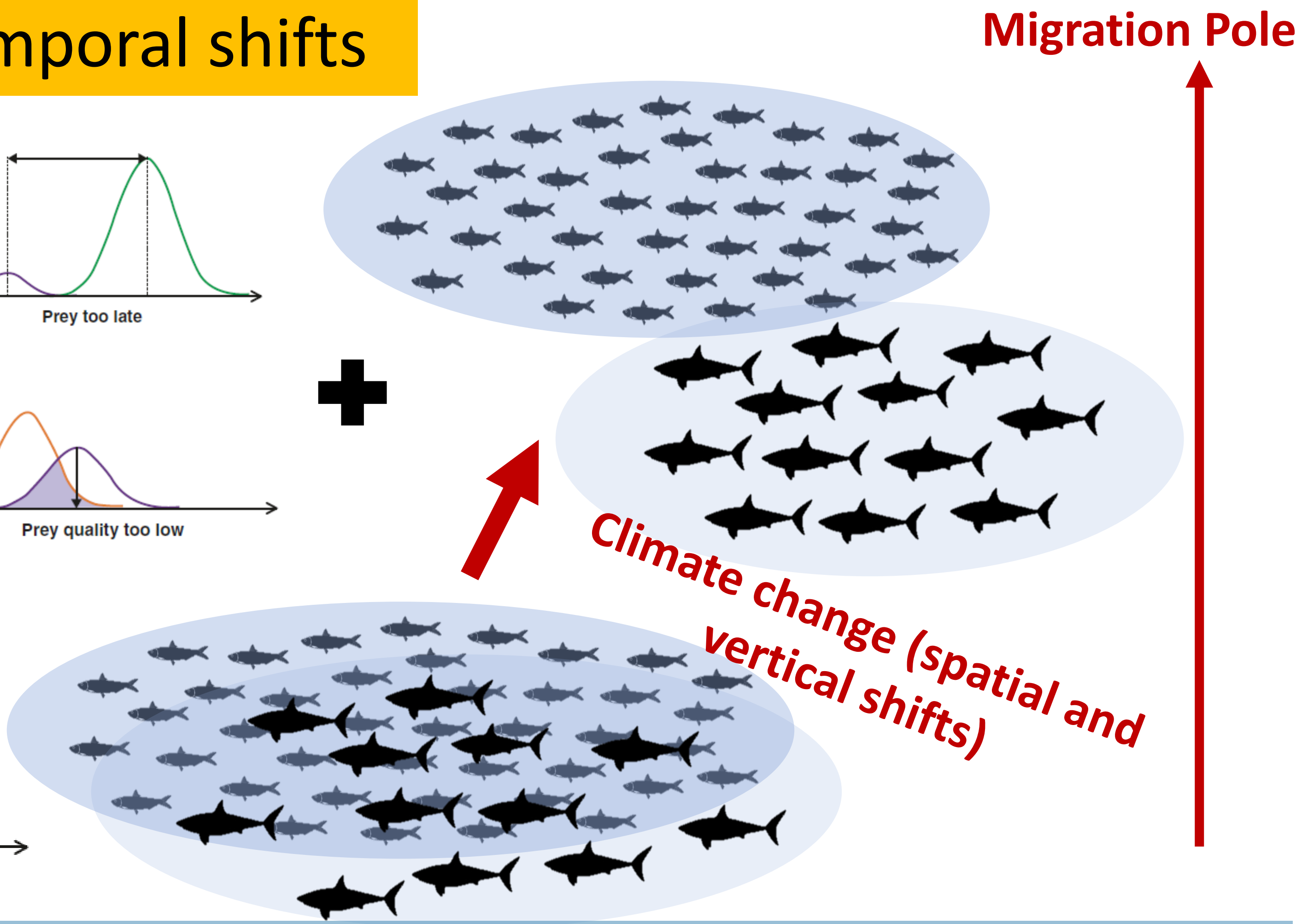
Schematic of range-shift dynamics in marine ectotherms in response to climate warming



Species already in warm environments probably cannot cope with a much warmer environment : extinction / migrate with increasing temperature to higher latitude where temperatures are cooler. Each species is in ecosystemic interaction.

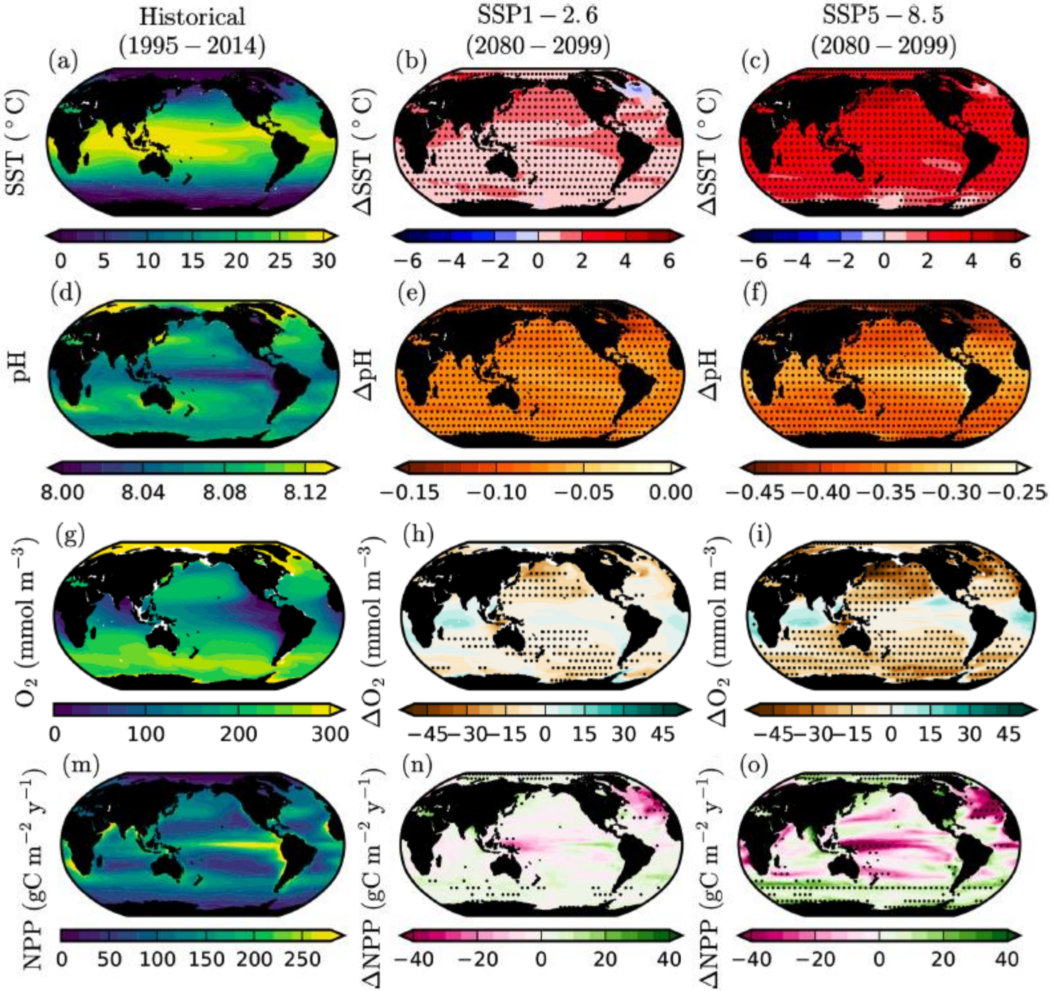
spatial and temporal shifts





Do we see that ? What is projected to happened ?

a few top climate Impact-drivers from ocean global models, 2021



- 02 has declined by ~2% in the past 70 years and is projected to decline by 2% in 2.6 and ~4% globally in 8.5 by 2100.

- While models ~ agree on the SST (warming) and pH (acidification) in the future everywhere, the agreement is much lower in models for oxygen and primary production in the tropics.

- Caution for studies where oxygen and primary production are used in future climates, in the tropical band more particularly (will come back to that).

- Obviously, **regional changes** are even more **uncertain** than basin averages.

Short summary of impact of CID on marine organisms.

- Below the optimum temp, warming affects species by accelerating a range of metabolic processes that influence life stage duration, growth rates, energetic demand, depending on physiology. It influences phenology. Eurytherms are more plastic than ectotherms but warmer water eurytherms are less adaptative than temperate species. Temperature is a major (and the most well-known) climate-driver for almost all marine and terrestrial species

- Primary productivity fate is also crucial for sustainable ecosystem because phytoplankton is the base of the ocean food web and ultimately provides energy for most organisms in higher trophic levels.

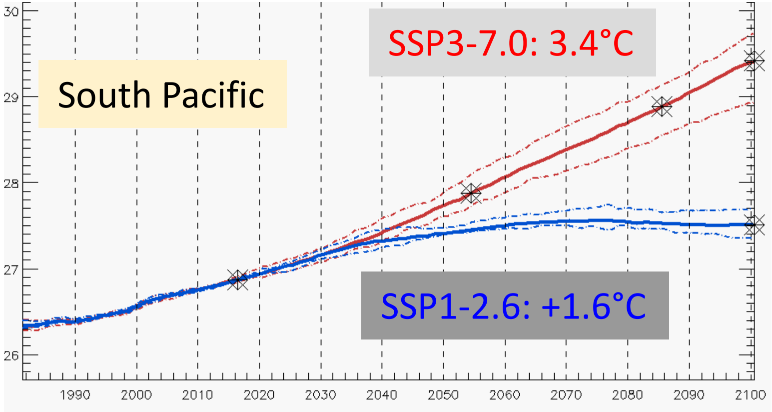
- Decreases in oxygen concentration can limit the depths that can be occupied by fishes leading to habitat compression. (e.g Albacore are limited by O2 in the eastern Pacific)

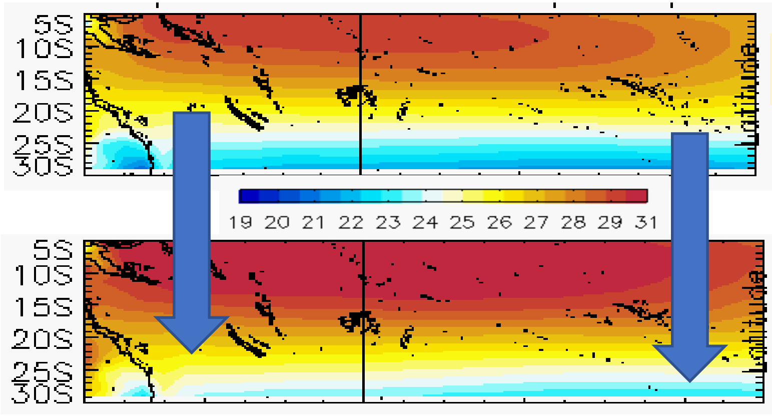
- Such changes in the depth distribution of fishes can affect interactions between predators and prey, as well as interactions between fisheries and their target species

- ocean acidification, decreasing oxygen concentration, declining primary productivity have the capacity to negatively impact fishes but temperature may be beneficial or not depending on tuna species.

- In the tropical Pacific, direct effects of ocean acidification are expected to have larger effects on coastal fishes than open ocean species, such as tuna, especially because coral reef ecosystems are directly impacted by acidification : e.g: shift from coral dominated to algal dominated ecosystems

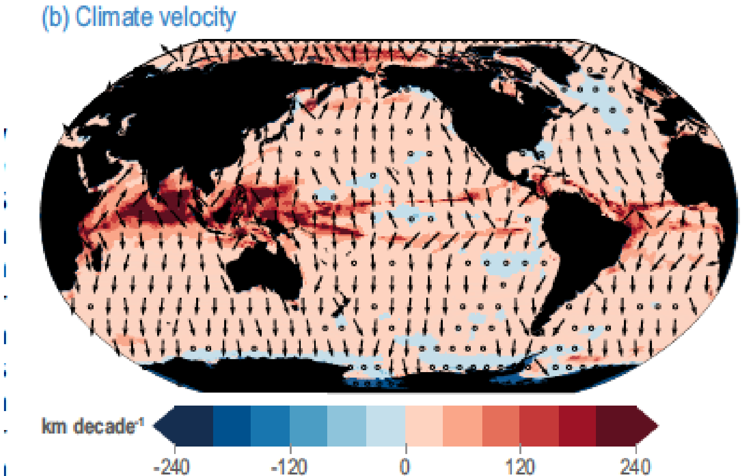
Another key driver: Ocean Climate Velocity : a measure of how fast the temperature expands spatially due to warming





Present-day

Future (2080-2100) SSP3-7.0

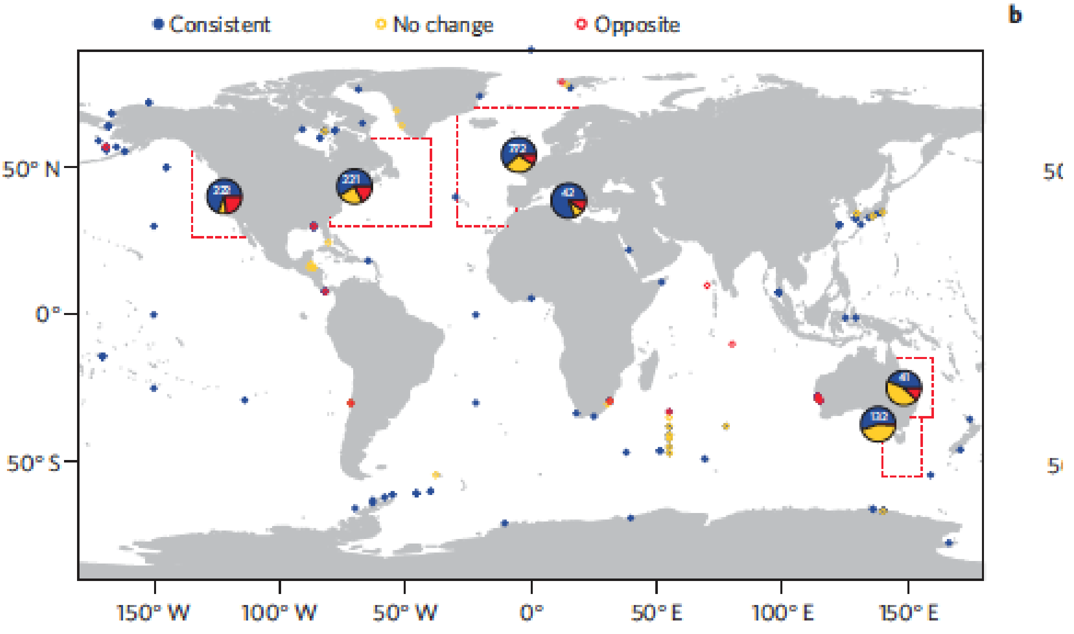


We can calculate a rate at which isotherms move spatially ~at present : > 30 km/decade in the Pacific since 1960 With faster isotherm displacement near the equator

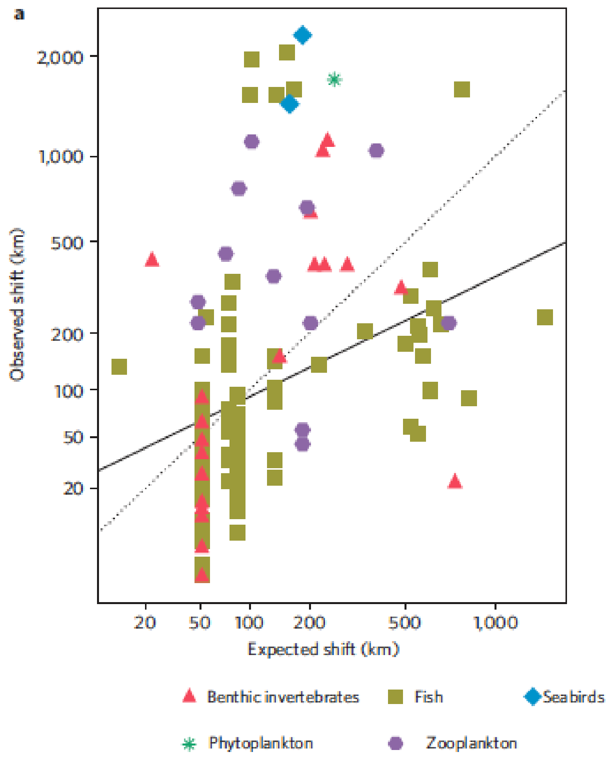
In the vertical, 20°C isotherm deepening at ~ 3 meters/decade are estimated.

Burrows et al., 2011, 2019.

Observed climate shifts ?



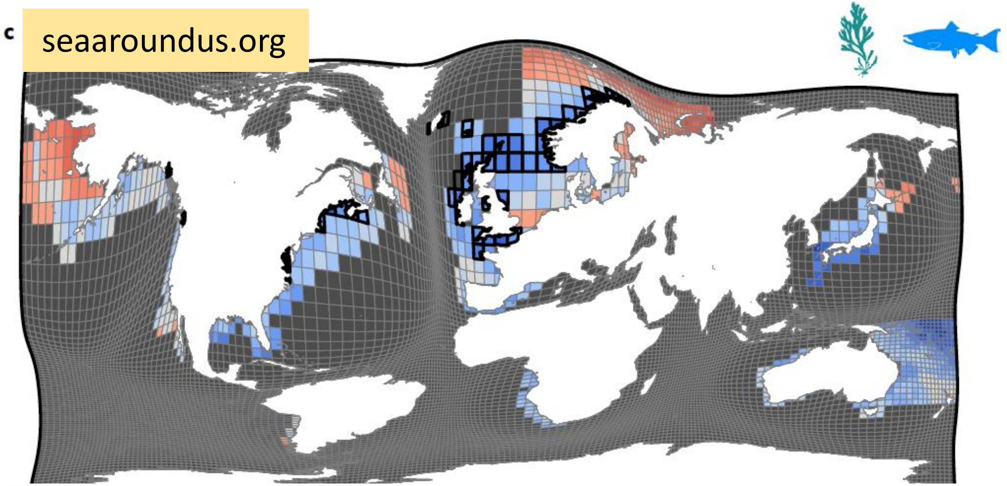
A meta analysis of published studies (360 species), Poloczanska et al; NCC 2013 1960-2009

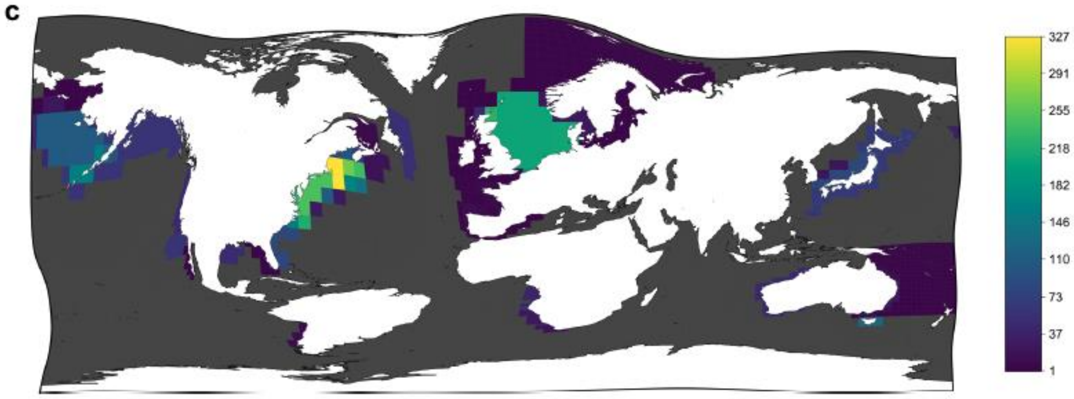


"consistent" but R^2=0.11 and observed shift are half as slow as expected from the climate velocity index.

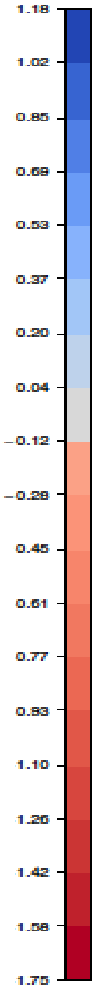
Studies are not really global in general due to data availability, and, as we will see, strong extrapolation has to be made in general

Observed species shifts ?





Extended Data Fig. 1 | Cartograms of the spatial sampling effort in the geo-database. Number of taxa per 2° × 2° grid cell for a, elevational and b, c, latitudinal range shifts across the terrestrial (a, b) and (c) marine realm.



Here, local change of species can either be linked to local extinction or to movement. The method tests the coherence between species shifts and velocities of isotherms.

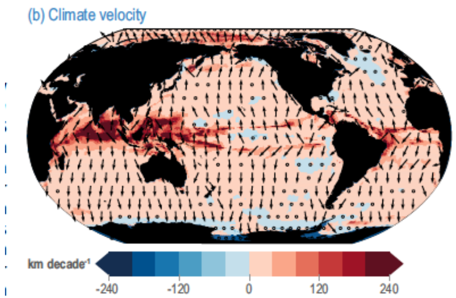
Marine species are found to move 6 times faster than terrestrial ~60km/decade

the model linking climate velocities explains 33% of the species shifts for marine species.

the data is in fact geographically limited especially in the tropics

Spatial shifts: and so what happens in the future ?

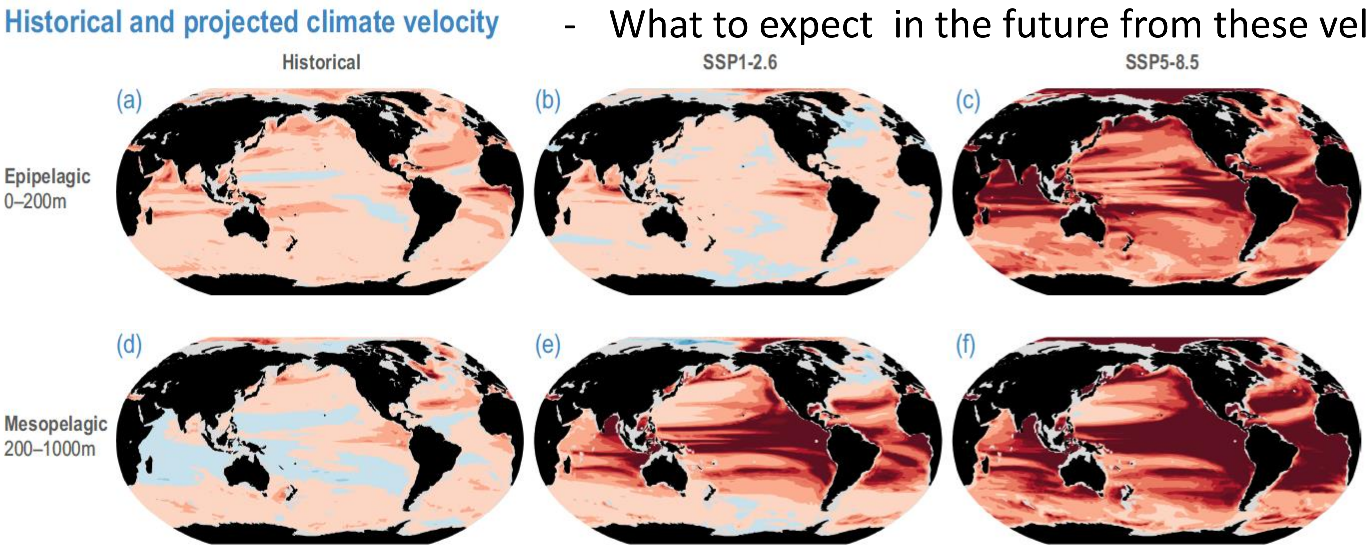
Observed velocity: 1925-2016



- We first note that the models over the present period do not exactly match the observed.

- The mesopelagic layer will experience much higher climate velocities in the tropics, like > 240 km/decade even in scenario 2.6 ? If species followed rather than adapt, that would have considerable consequence on SIDS resources….

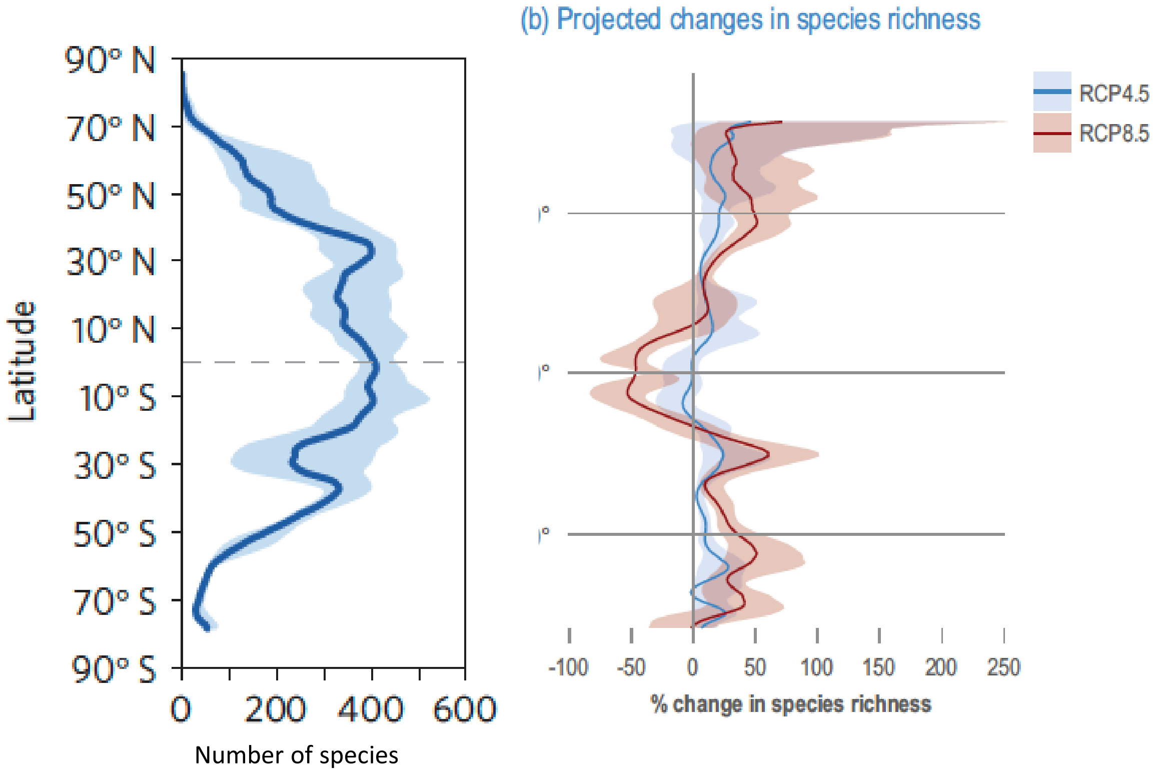
- What to expect in the future from these velocities ?



IPCC, 2022, Kwiatkowski et al., 2020

Spatial shifts: biodiversity: number of species (richness). Statistical “niche” modeling

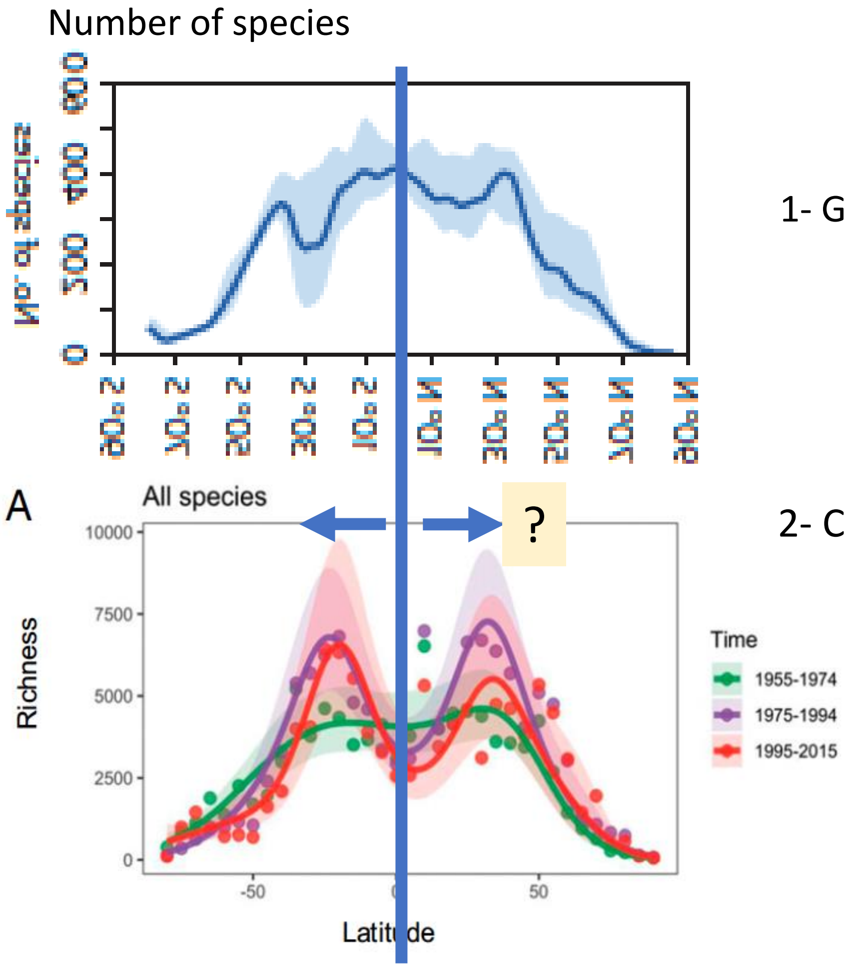
Using a model with ~19 000 species (aquamap) and their thermal habitat, Garcia Molinos used these climate velocities to infer what may be the 2100 species richness compared to present-day



Garcia-Molinos et al., NCC, 2016

Richness here =number of species (one measure of biodiversity)

The equatorial region would loose biodiversity in the worst case scenario while the subtropics would gain biodiversity. The turn over rate (local extinction/ migration) is projected to be ~40% in the tropics) uncertainties: still debating how visible that is.

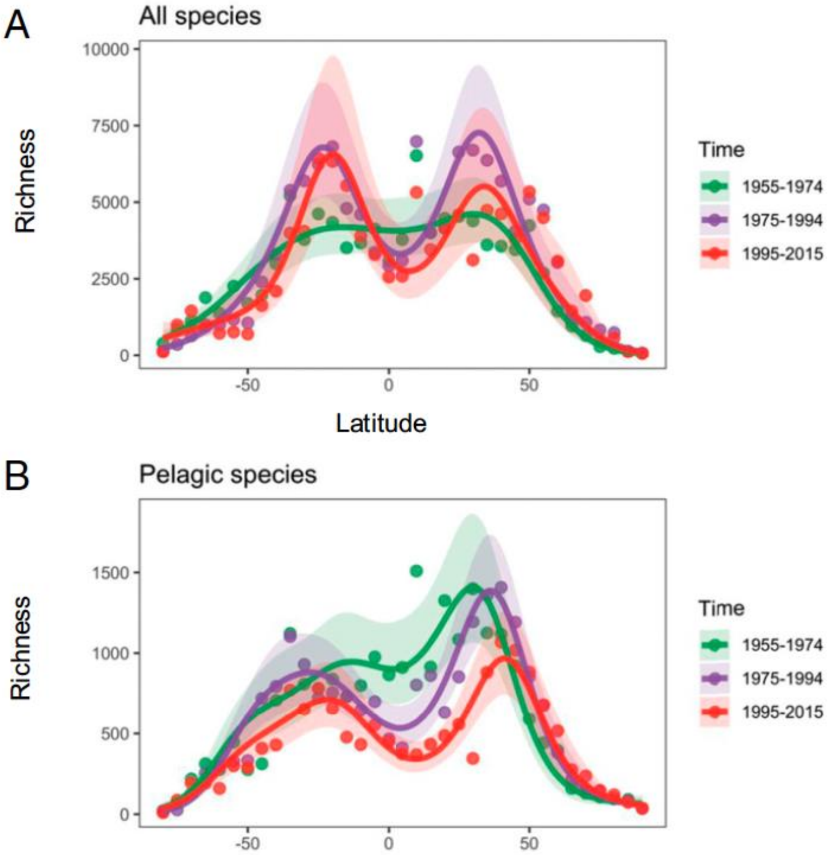


1- Garcia-Molinos et al. (19 000 Garcia-Molinos) aquamap

2- Chaudhary et al., 2021, OBIS, 60 000 observations

There are still large uncertainties in the data and in the modelling on that aspect, because the data is still sparse. Regional

Biodiversity: data distribution of Chaudhary. Still not enough



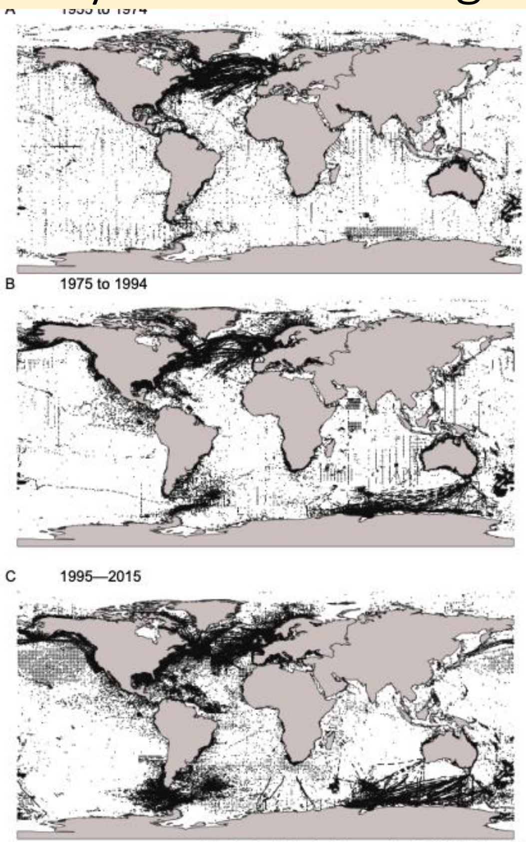
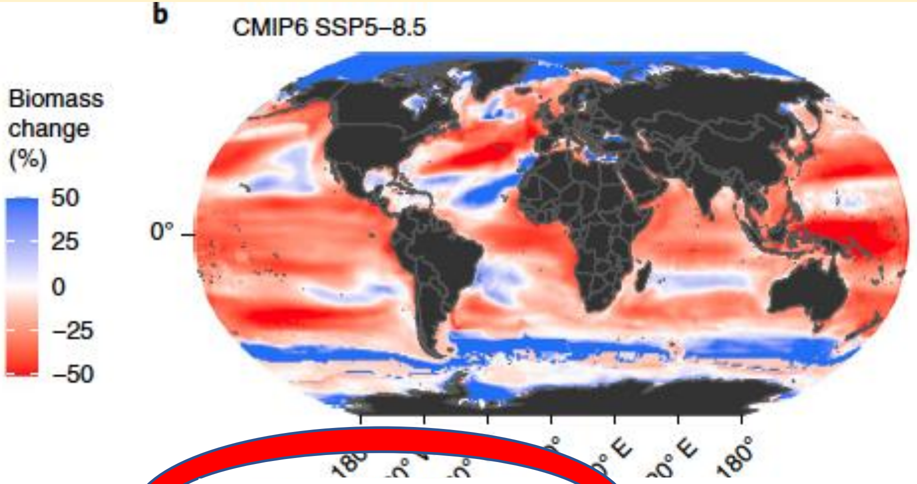


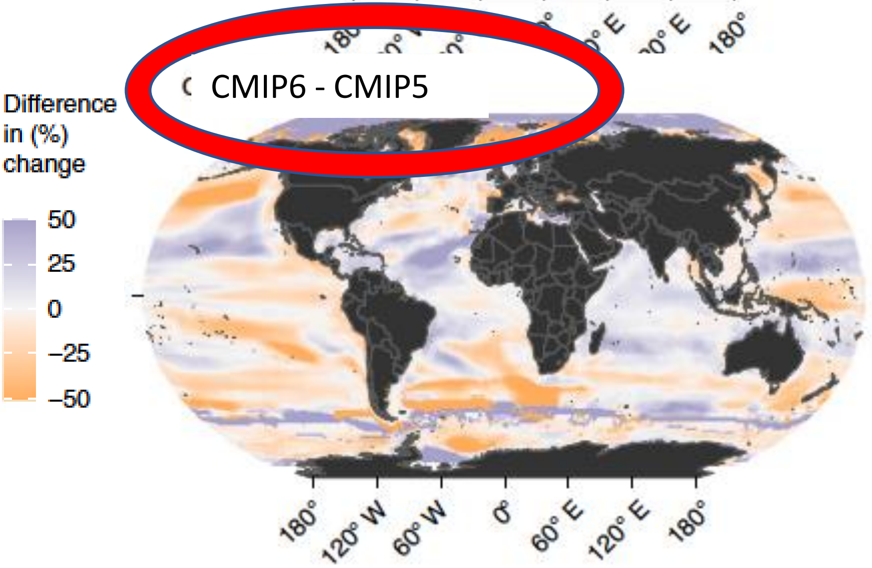
Fig.S3. Sampling coverage (black dots) in the time period: (A) 1955—1974, (B) 1975—1994 and (C) 1995—2015.

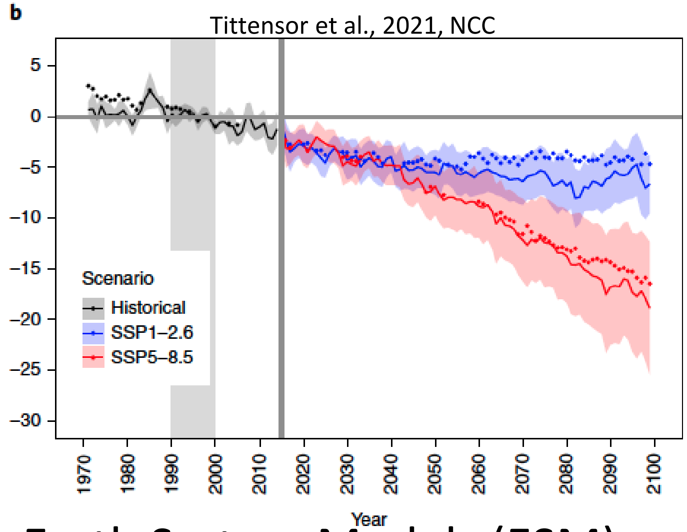
Chaudhary et al., 2021

However, the data sampling is really not uniform especially for the open ocean in the Pacific, as in previous studies. The density of observations precludes “local” conclusions

Next: marine biomass in general (> 10cm animals): ecosystem models)





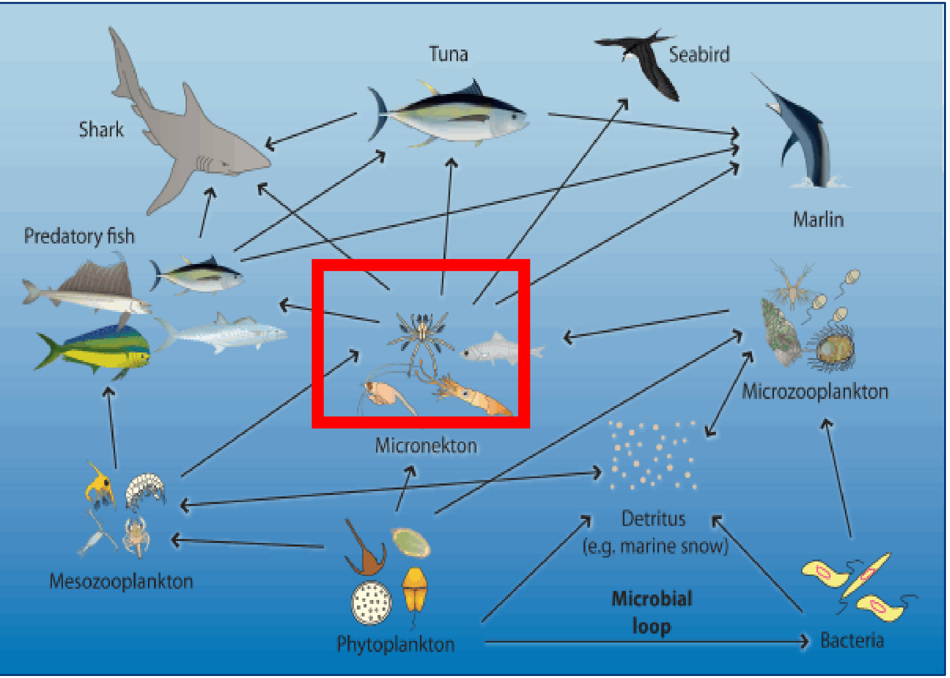


The Earth System Models (ESM) are overall consistent despite NPP and O2 being very different.

This suggests that temperature is a main and strong driver overall in these complex models. (IPCC, 2022)

However, “regional” changes cannot be confidently assessed

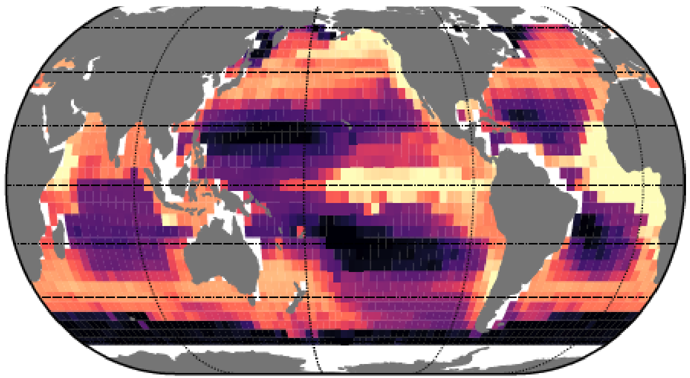
“Observed” marine biomass (another example specific to micronekton).



Ship-Borne acoustics as a proxy (ariza et al., 2021)

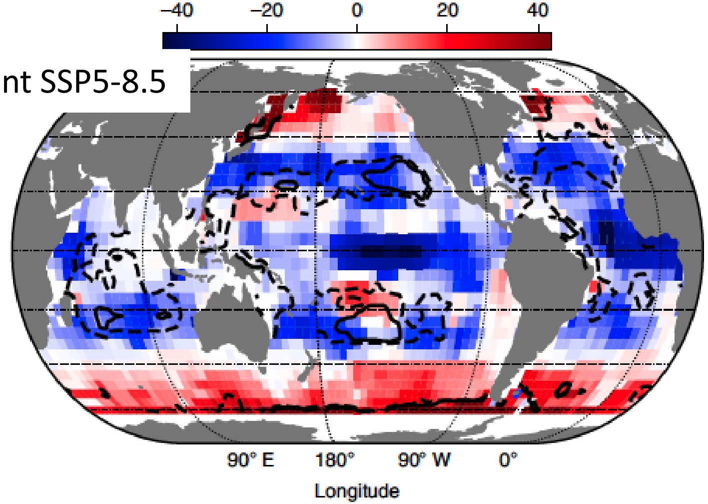
“Observed” marine biomass (example micronekton): niche modelling

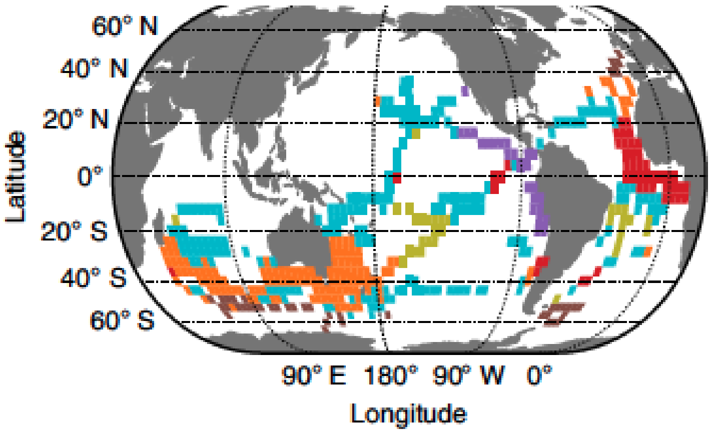
Present observed acoustic micronecton.



Ariza et al., 2021 NCC

Future – Present SSP5-8.5





~Similar signs as ecosystem models = reduced micronekton in the tropics in the future and potential increase in the subtropics, **although amplitude and regional patterns cannot be assessed confidently**

Based on limited observations !! Again crucial point in being able to acquire observation to fill up these gaps

Last but not least, corals

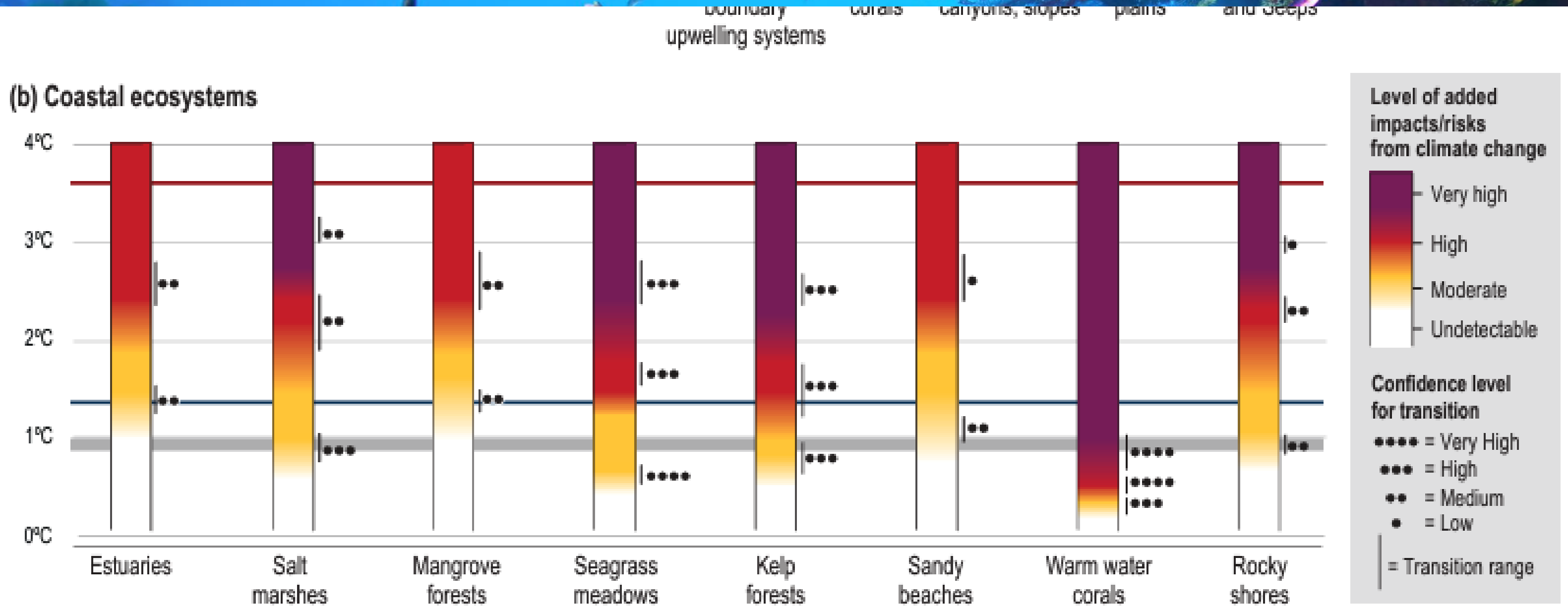
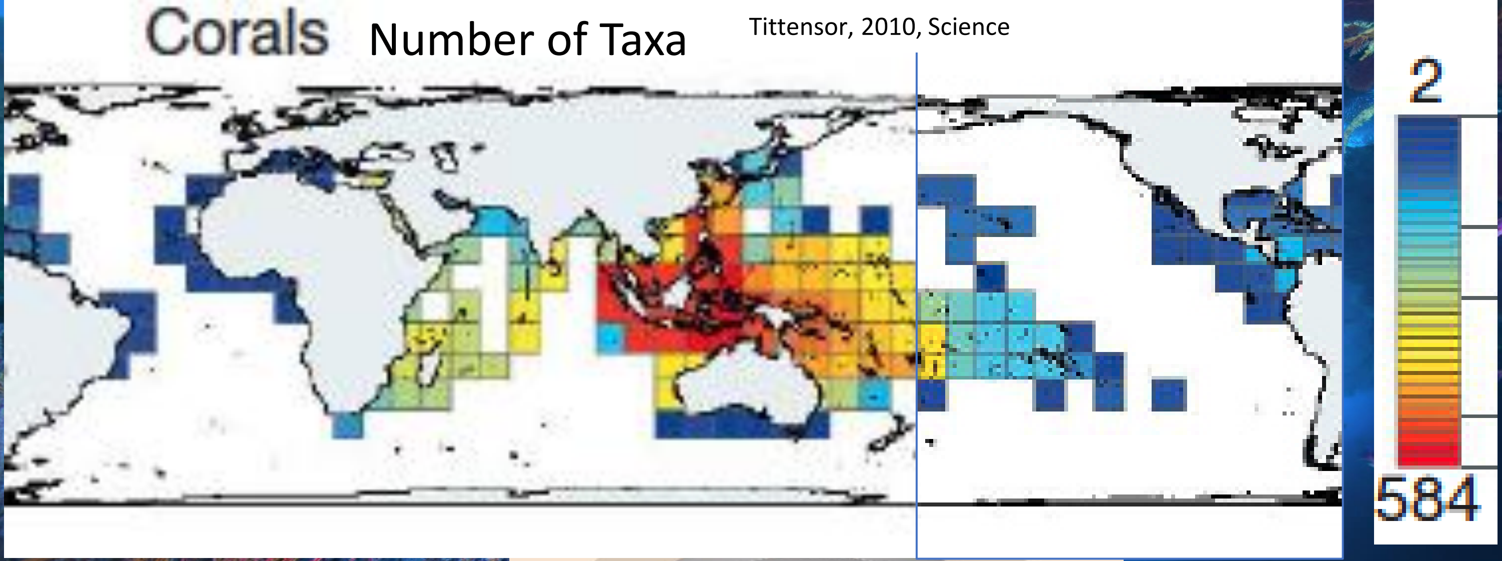


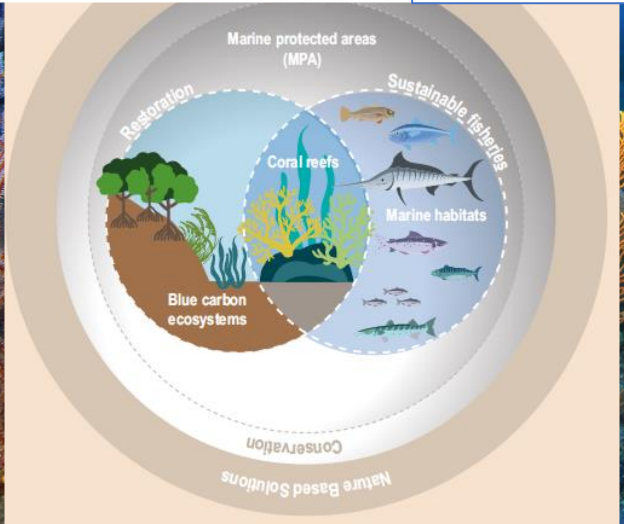
Figure 5.16 | Risk scenarios for open ocean (upper panel) and coastal (lower panel) ecosystems based on observed and projected climate impacts. 'Present day' corresponds to the 2000s, whereas the different greenhouse emissions scenarios: Representative Concentration Pathway (RCP)2.6 and RCP8.5 correspond to year 2100. Multiple climatic hazards are considered, including ocean warming, deoxygenation, acidification, changes in nutrients, particulate organic carbon flux and sea level rise (SLR) (see sections 5.2 and 5.3). The projected changes in sea surface temperature (SST) from an ensemble of general circulation models (left panels) indicate the level of ocean changes under RCP2.6 and RCP8.5 (see Cross Chapter Box 1 Table CB1 for the projected global average changes in average air temperature, SST and other selected ocean variables). Global average impacts/risks are represented. Regional variations of risks/impacts are described in Section 5.2.5, 5.3.7, SM5.2 and SM5.5. Impact/risk levels do not consider human risk reduction strategies such as societal adaptation, or future changes in non-climatic hazards. The grey vertical bars indicate the transition between the levels of risks, with their confidence level based on expert judgment. Note: The figure depicts climate change impacts and risks on warm water corals taken from SR15, based on global models. Observed impacts on coral reefs ecosystems outlined in Section 5.3.4 and Box 5.5 reveal a more complex situation that may result in regional differences in confidence levels.

Number of Taxa

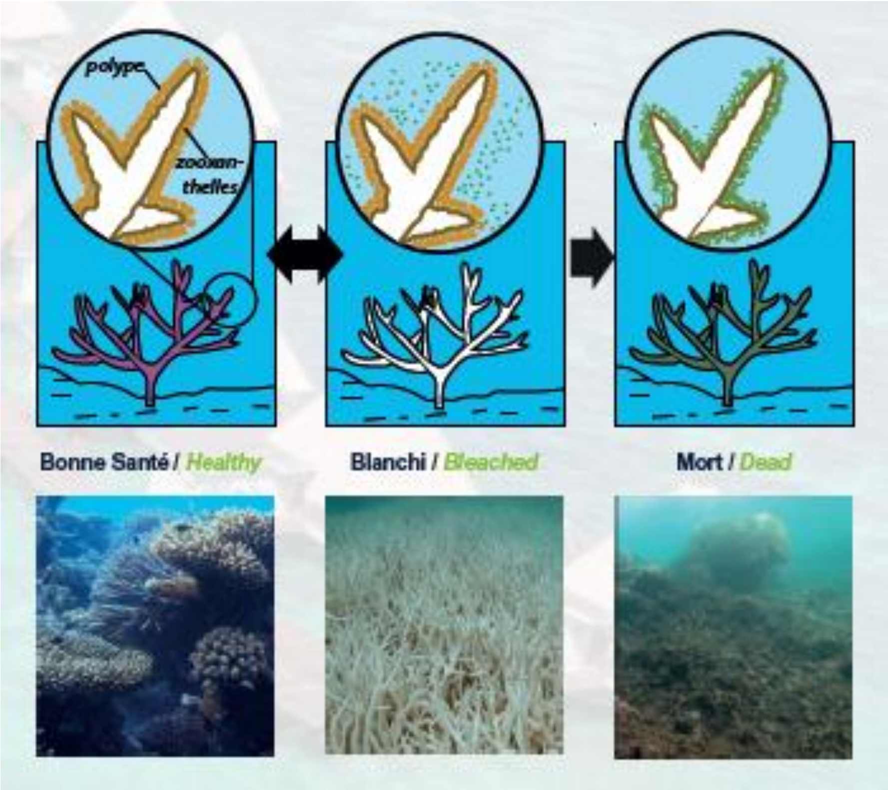
Tittensor, 2010, Science

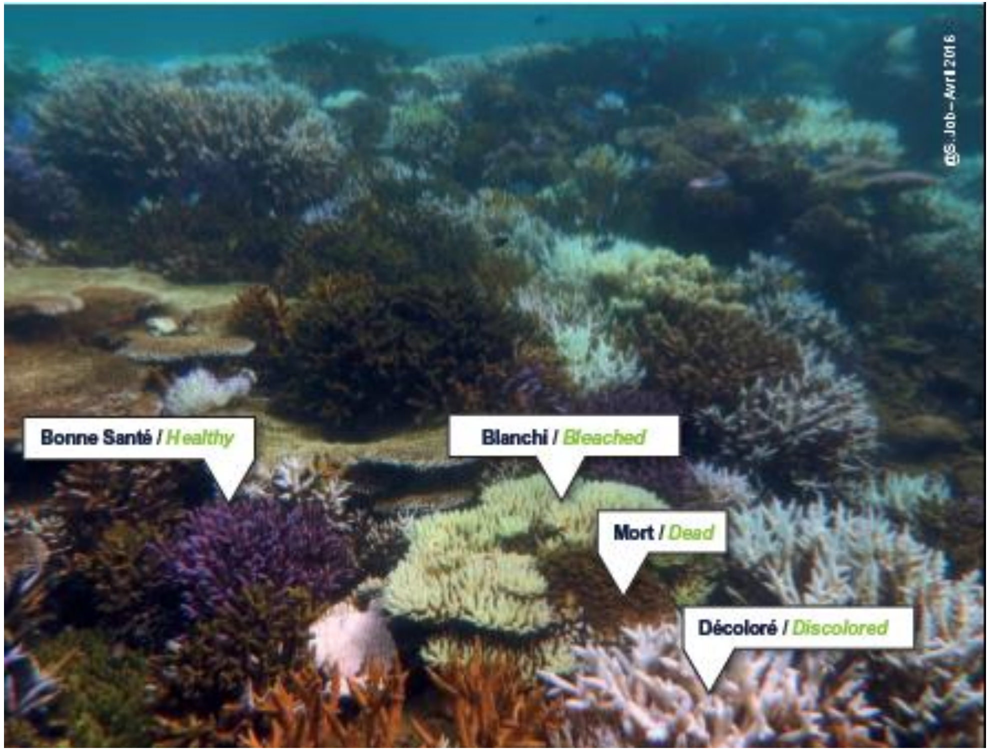


Golden Triangle, Hot Spot of biodiv in the Indo-Pacific

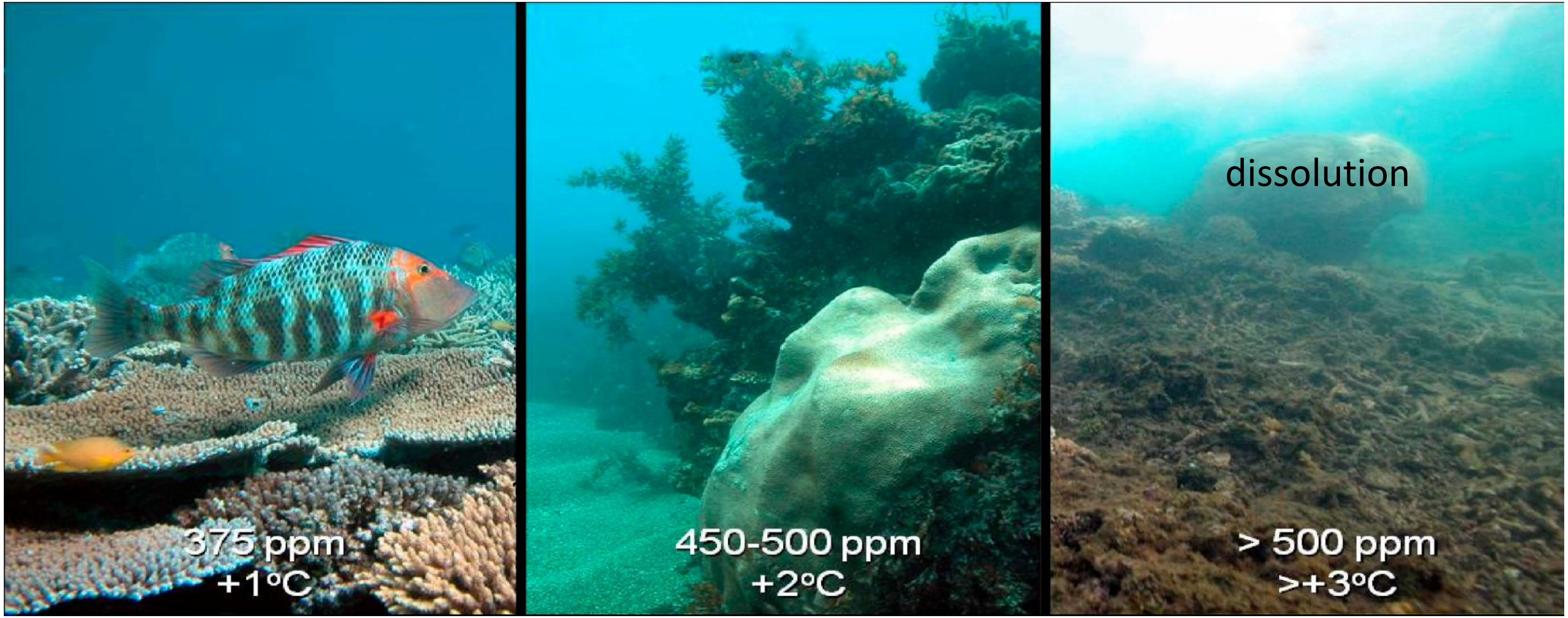


Coral Bleaching, a reminder





That ecosystem is particularly vulnerable to both temperature and CO_2 because of carbonated skeletons!



Hoegh-Guldberg, 2007 Science. Right Now, we are at 420 ppm

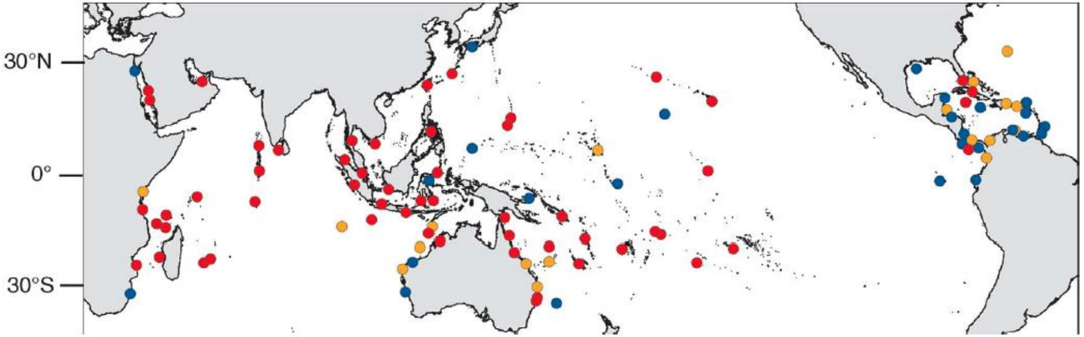
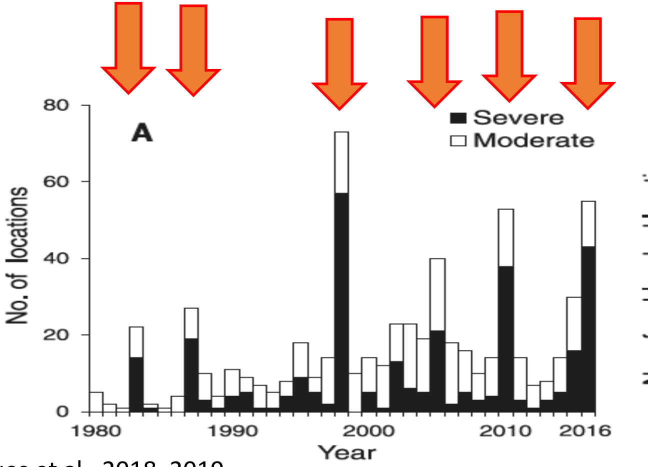


Fig. 3. The global extent of mass bleaching of corals in 2015 and 2016. Symbols show 100 reef locations that were assessed: red circles, severe bleaching affecting >30% of corals; orange circles, moderate bleaching affecting <30% of corals; and blue circles, no substantial bleaching recorded. See table S1 for further details.

Hughes *et al.*, *Science* 35

El Niño years

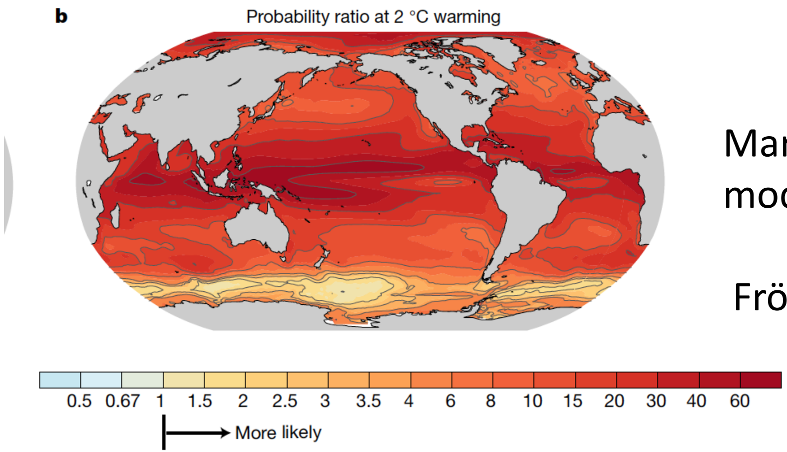


Hugues et al., 2018, 2019

Benzoni et al. Ilot Canard, New Cal. , february 2016

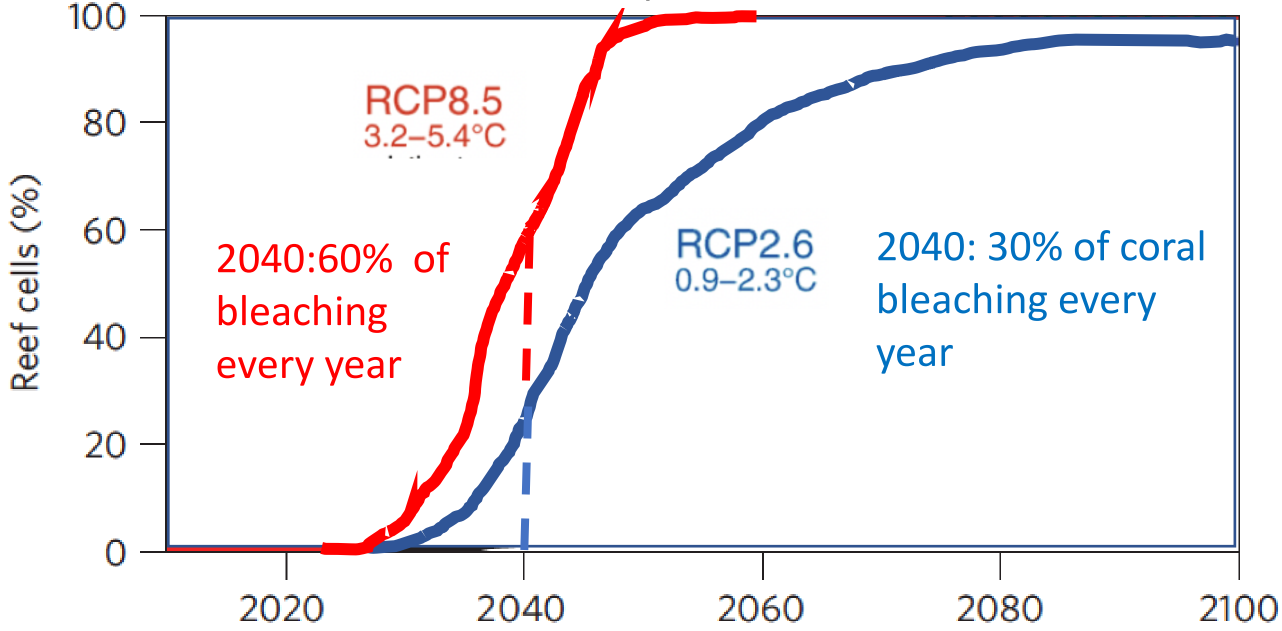
There is a strong association between massive bleaching and heat waves, here El Nino phenomenon

Future of corals



Marine Heat waves in the future, at moderate warming (2.6)

Frölicher et al. 2018



- Without adaptation/restoration, coral have a bleak future pretty soon !
- Even if anthropogenic warming is limited to 1.5 °C, 70–90% of existing reef-building corals are expected to be lost by the end of the century

Hope. Some are “super corals”. Adaptation ?

CO_2, vents, Ambitle region, Papua New Guinea. They provide natural conditions for studying the effect of ocean acidification on the physiology of coral. ©IRD/J-M. Boré.

Coral communities (more than 50 species of corals) associated with the mangrove of Bouraké, New Caledonia. They are exposed to pH, oxygen and temperature values close to those expected in 2050. This site is a natural laboratory providing the ideal conditions to study the effect of climate change on corals ©IRD/S. Andréfouët.

Conclusions (1)

- Phytoplankton: Overall, the response of phytoplankton to the interactive effects of multiple drivers is complex, and presently ESMs do not resolve the full complexity of their physiological responses precluding a clear assessment of the effects of these regional distinctive multi-stressor patterns

- Zooplankton: there is high agreement in model projections that global zooplankton biomass will very likely reduce in the 21st century, with projected decline under RCP8.5 almost doubled that of RCP2.6 (very likely). However, the strong dependence of the projected declines on phytoplankton production (low confidence) and simplification in representation of the zooplankton communities and foodweb render their projections having low confidence.

- Epipelagic fish: Globally, the general direction of range shifts of epipelagic fishes is poleward. Polewards range shifts are projected to result in decreases in species richness in tropical oceans, and increases in mid to high-latitude regions leading to global-scale species turnover. Low confidence on magnitude because of model uncertainties, data uncertainties and limited number of published studies

- Species turnover (species replacements due to extinction+migration) relative to their present day richness in the tropical oceans (30ºN–30ºS) is projected to be 14–21% and 37–39% by 2031–2050 and 2081–2100 under RCP8.5 (ranges of mean projections from two sets of simulation for marine fish distributions).

Conclusions (2)

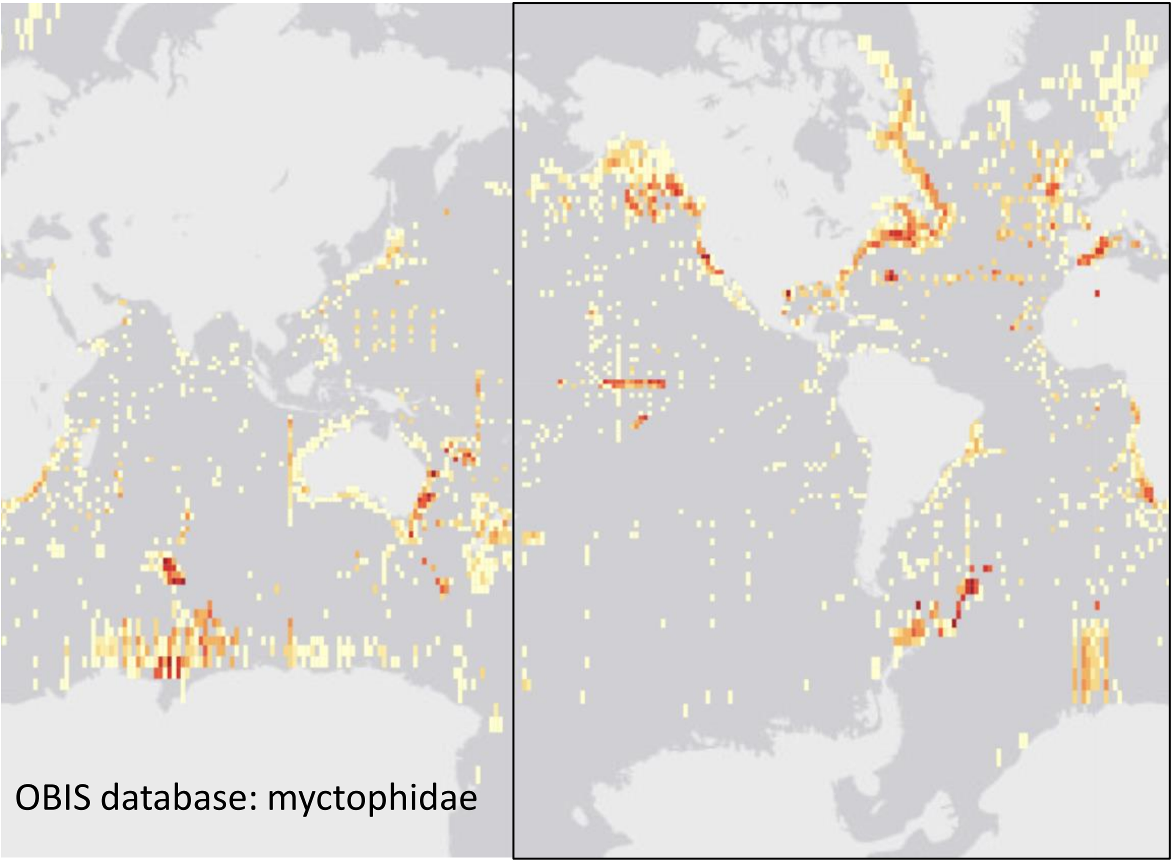
- Open ocean Animal biomass .Overall, potential total marine animal biomass is projected to decrease by 4.3 ± 2.0% and 15.0 ± 5.9% under RCP2.6 and RCP8.5, respectively, by 2080–2099 relative to 1986–2005, while the decrease is around 4.9% by 2031–2050 across all RCP2.6 and RCP8.5 (very likely). FishMips model comparison.

- Total animal biomass decreases largely in tropical and mid-latitude oceans but low confidence in the regional patterns

- Accounting for the removal of biomass by fishing exacerbates the decrease in biomass for large-bodied animals which are particularly sensitive to fishing..

- Based on findings from simulation modelling, "coral reefs are projected to decline by a further 70–90% at 1.5ºC (very high confidence) with larger losses (>99%) at 2ºC (very high confidence)". The variations in exposure, sensitivity and adaptive capacity between coral populations and regions are further projected to cause large changes in the composition and structure of the remaining coral reefs, with large regional differences

Last slide “ we don’t need no stink’n data ? (1992)”



PS. What we do in the climate field to go to high resolution in countries EEZs: regional downscaling: SPC climate Flagship