Perspective on fisheries and biodiversity in relation to climate change for a sustainable future

Andrea Belgrano, Swedish Institute for the Marine Environment

Background

FISHERIES

Impacts of historical warming on marine fisheries production

Christopher M. Free[1,2*,] James T. Thorson[3,4], Malin L. Pinsky[5], Kiva L. Oken1,[6], John Wiedenmann[5], Olaf P. Jensen[1]

Free et al., Science 363, 979–983 (2019) 1 March 2019

ECOLOGY

Improved fisheries management could offset many negative effects of climate change

Steven D. Gaines[1 *,] Christopher Costello[1] , Brandon Owashi[1†] , Tracey Mangin[1†] , Jennifer Bone[1†] ,
Jorge García Molinos[2,3,4] , Merrick Burden[5] , Heather Dennis[6] , Benjamin S. Halpern[1,7,8] ,
Carrie V. Kappel[7] , Kristin M. Kleisner[5] , Daniel Ovando[1]

Gaines et al., Sci. Adv. 2018; 4 : eaao1378 29 August 2018

ECOLOGY

Let more big fish sink: Fisheries prevent blue carbon sequestration—half in unprofitable areas

Gaël Mariani[1*,] William W. L. Cheung[2], Arnaud Lyet[3], Enric Sala[4], Juan Mayorga[4,5], Laure Velez[1],Steven D. Gaines[6], Tony Dejean[7], Marc Troussellier[1], David Mouillot[1,8]

Mariani et al., Sci. Adv. 2020; 6 : eabb4848 28 October 2020

The role of the oceans for life on Earth and Human well-being

Carry out 50% primary production on Earth

Supply 20% intake animal protein to more than 3 billion people

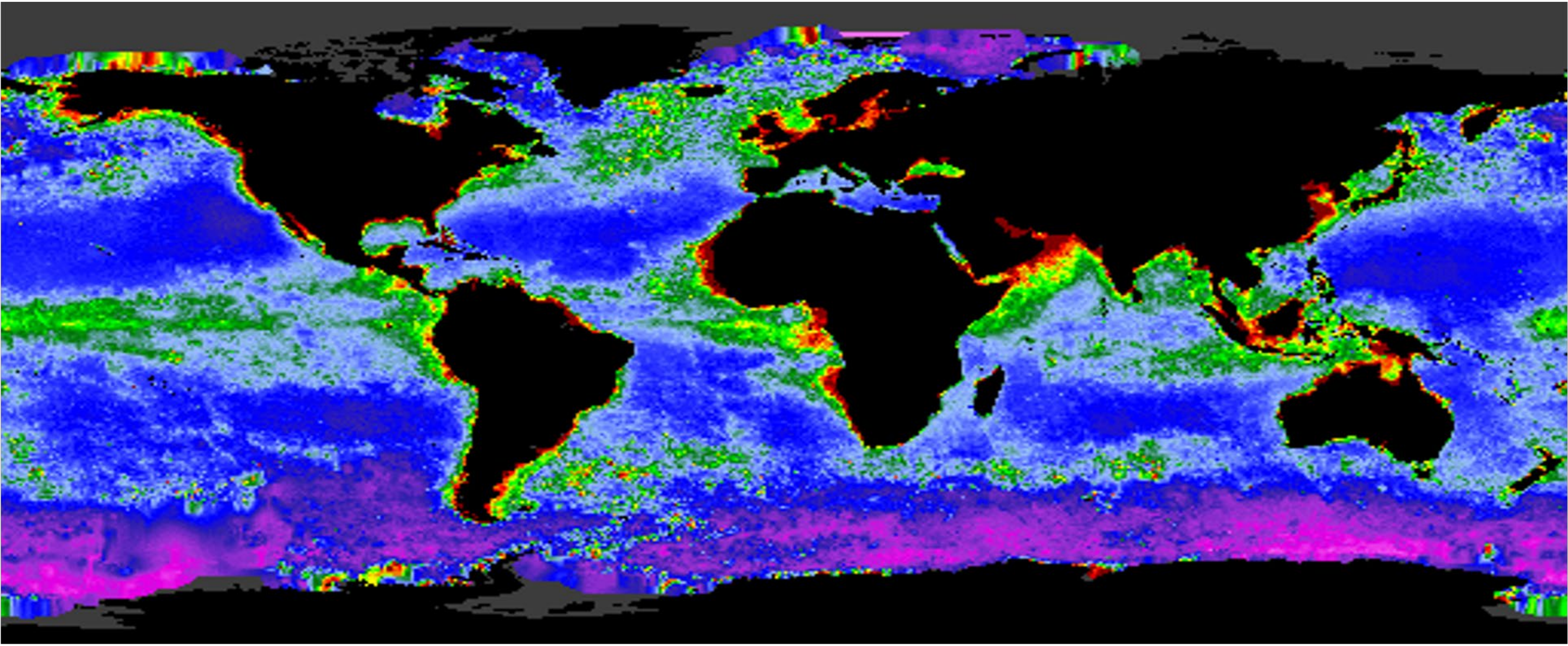
Support the greatest biodiversity on the Planet

OUTLINE

- Ocean Ecology
- Fisheries, Biodiversity and Climate
- IPCC scenarios and the CFP
- Perspective, Challenges and Actions

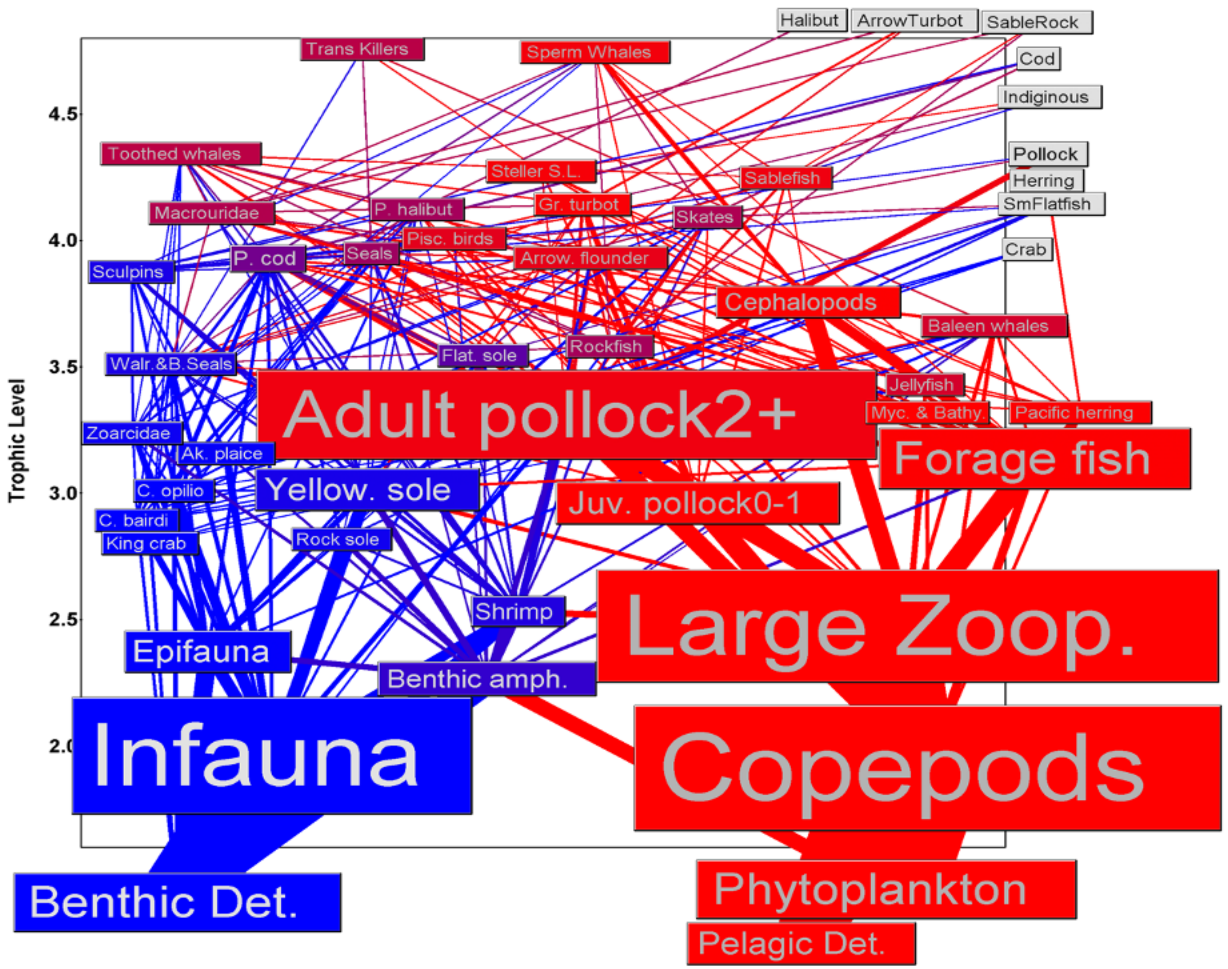
OCEAN ECOLOGY

Ecosystems are adaptive, complex systems and have emergent properties



(Levin, S. A. 2003, Complex adaptive systems: exploring the known, the unknown and unknowable. Bull. Am. Math. Soc.40, 3-19)

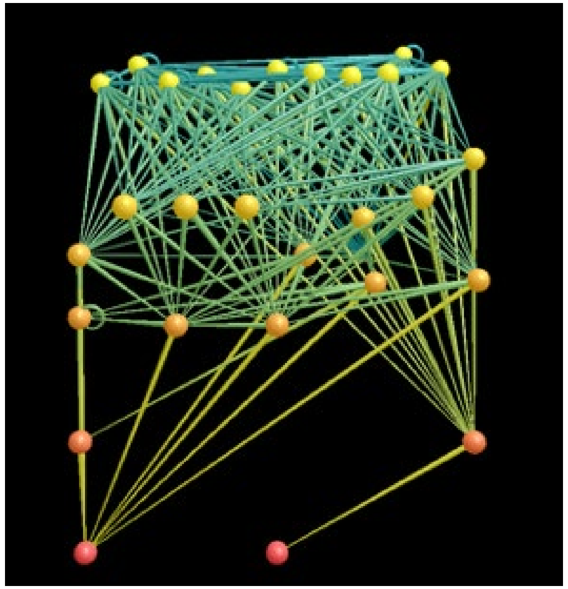
Food web complexity



The eastern Bering Sea food web as described in Aydin et al. 2002 Coloration indicates benthic energy (blue) and pelagic energy (red). From: (Aydin, K.Y., et al., 2002)

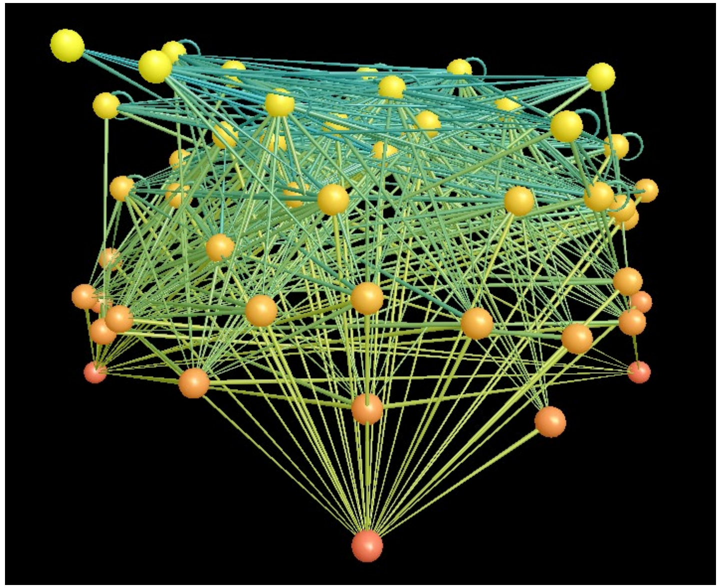
Food Webs Topology

Benguela, S. Africa



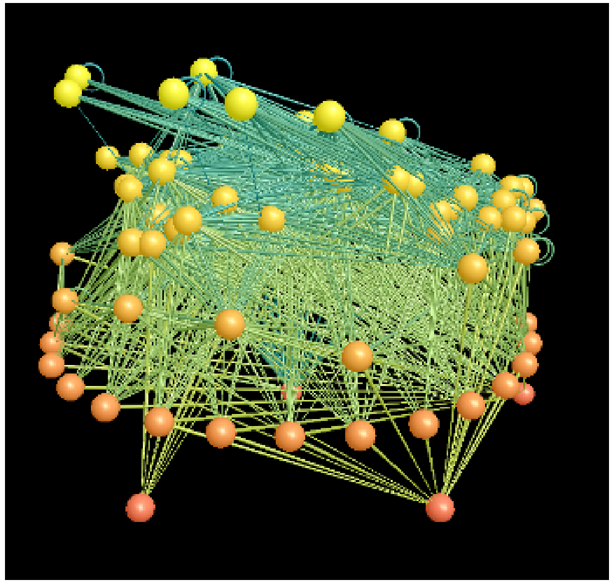
S = 29, C = 0.24

Caribbean Reef



S = 50, C = 0.22

NE US Shelf



S = 79, C = 0.24

The network structure of three marine food webs. Spheres represent "trophic species," which are taxa from an originally published food web that share the same set of predators and prey and are grouped together into a single node. Elongated cones represent feeding links, with the narrower part of the cone pointing to the prey taxon. Basal taxa (e.g., phytoplankton, detritus) are shown in red at the bottom of each food web, with highest trophic level taxa shown in yellow at the top. *S* = number of trophic species, *C* = connectance = *L*/*S*2, where *L* = feeding links. Images produced with FoodWeb3D software written by R. J. Williams and available through www.foodwebs.org. *Belgrano, A., Dunne, J. A., and Bascompte, J. (2008) Food Webs, Encyclopedia of Ocean Sciences, Elsevier*

Spooner et al. 2020. Using Integrated Ecosystem Assessments to Build Resilient Ecosystems, Communities, and Economies. COASTAL MANAGEMENT https://doi.org/10.1080/08920753.2021.1846152

FISHERY, BIODIVERSITY. AND CLIMATE

- Fishery, Biodiversity and Maximum Sustainable Yield (MSY) concept
- MSY reference points under climate change scenarios
- Linking CFP and MSFD

MSY concept

- The MSY concept establishes that harvested species should be maintained or restored at levels which can generate the highest rate of reproduction, which would yield the highest future catch rates.

- The fishing mortality-based (F-based) rate F_{msy} reference point correspond to the average yield = MSY and to the target reference point in the CFP directly linked to fishing effort.

- The biomass-based (B-based) B_{msy} reference points correspond to the biomass neded to provide MSY, and it is influence by the ecosystem state.

MSY reference points estimation

- Recent work have shown the possibility to estimating MSY reference points in a multi-species context, and the possibility to set harvest strategies based on MSY that account for fish stock and predator-prey interactions, and climate driven processes.

- Spatial Individual-based multispecies model OSMOSE to estimate F_{msy} using the climate scenarios RCP 4.5 and RCP 8.5.

Travers-Trolet M, Bourdaud P, Genu M, Velez L and Vermard Y (2020) The Risky Decrease of Fishing Reference Points Under Climate Change. Front. Mar. Sci. 7:568232. doi: 10.3389/fmars.2020.568232.

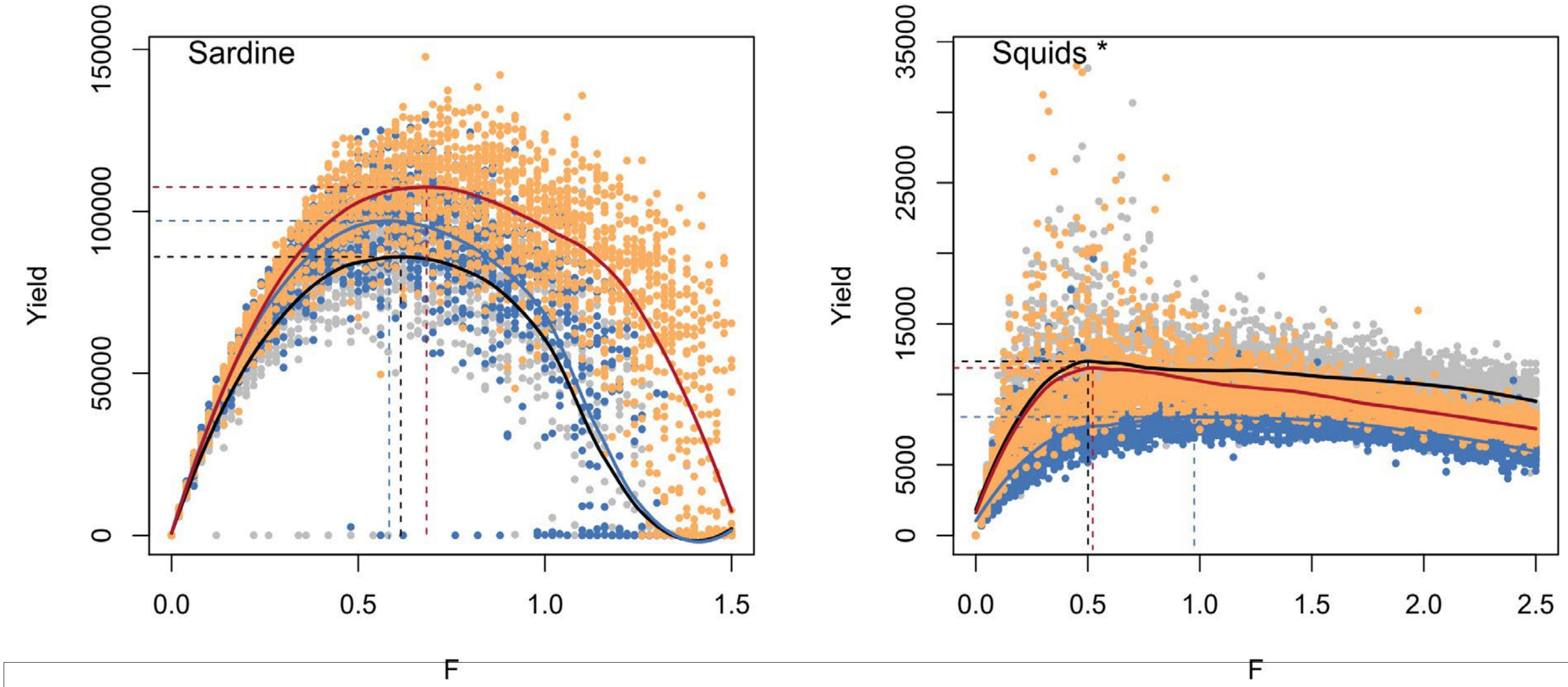


FIGURE 1 | Evolution of yield with fishing mortality rate (F) for each species, under historical conditions (gray and black), and under climate change scenarios RCP 4.5 (blue) and RCP 8.5 (orange and red). Dots correspond to the simulated yield (using 30 replicates) and the line corresponds to the adjusted loess function. Horizontal dashed lines indicate MSY, and vertical dashed lines indicate F_{MSY} for most species and F_{95MSY} for species for which the curve shows a plateau (indicated by * next to species name).

From: Travers-Trolet M, Bourdaud P, Genu M, Velez L and Vermard Y (2020) The Risky Decrease of Fishing Reference Points Under Climate Change. Front. Mar. Sci. 7:568232. doi: 10.3389/fmars.2020.568232

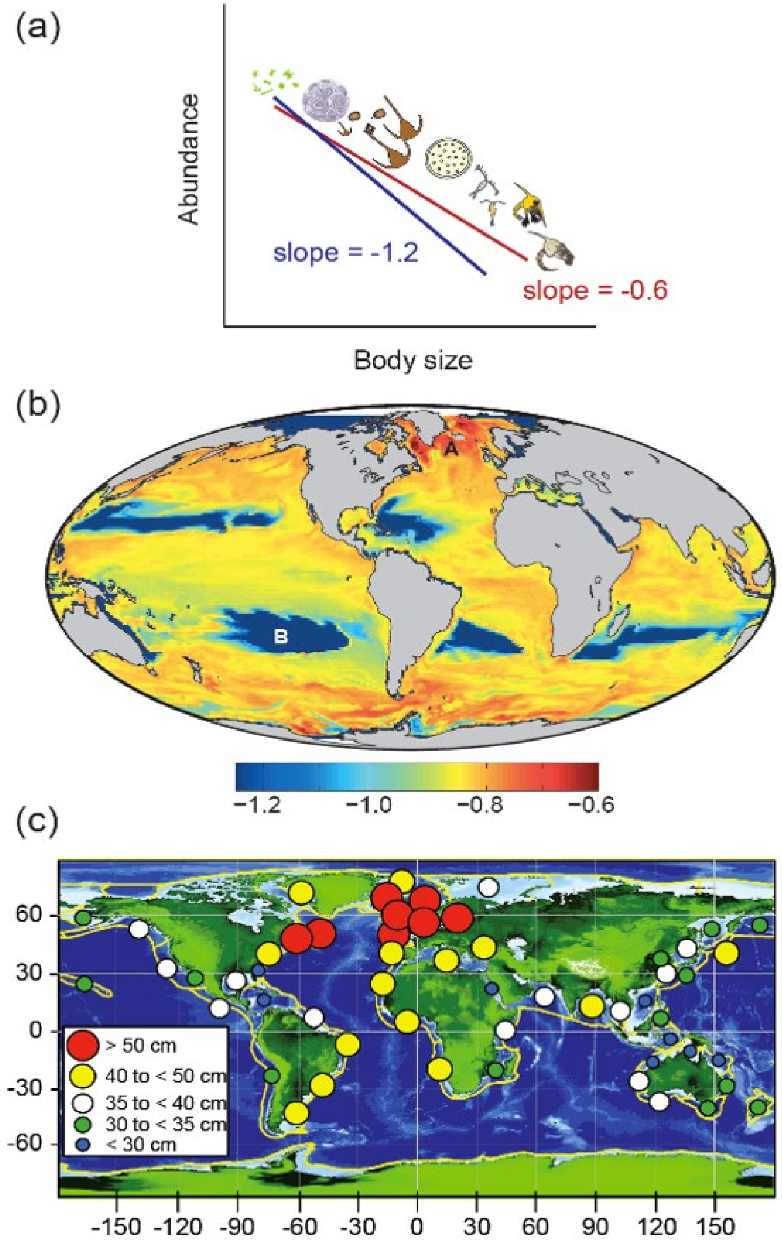
MSY reference points estimation

- Travers-Trolet M, et al. 2020, showed the possibility to account for climate change impacts suggesting targeting smaller fishing mortality then F_{msy} for moving towards a more sustainable fisheries management.

- As suggested by Mariani et al. (2020), the MSY concept needs to be reformed to set biomass at a level above MSY; >Bmsy, where Bmsy, is the biomass that would provide the highest long-term average catch.

Mariani, G., Cheung, W., Lyet, A., Sala, E., Mayorga, J., Velez, L., et al. (2020). Let More Big Fish Sink: Fisheries Prevent Blue Carbon Sequestration-Half in Unprofitable Areas. Sci. Adv. 6 (44), Eabb4848. doi: 10.1126/sciadv.abb4848

Macroecology and Biodiversity



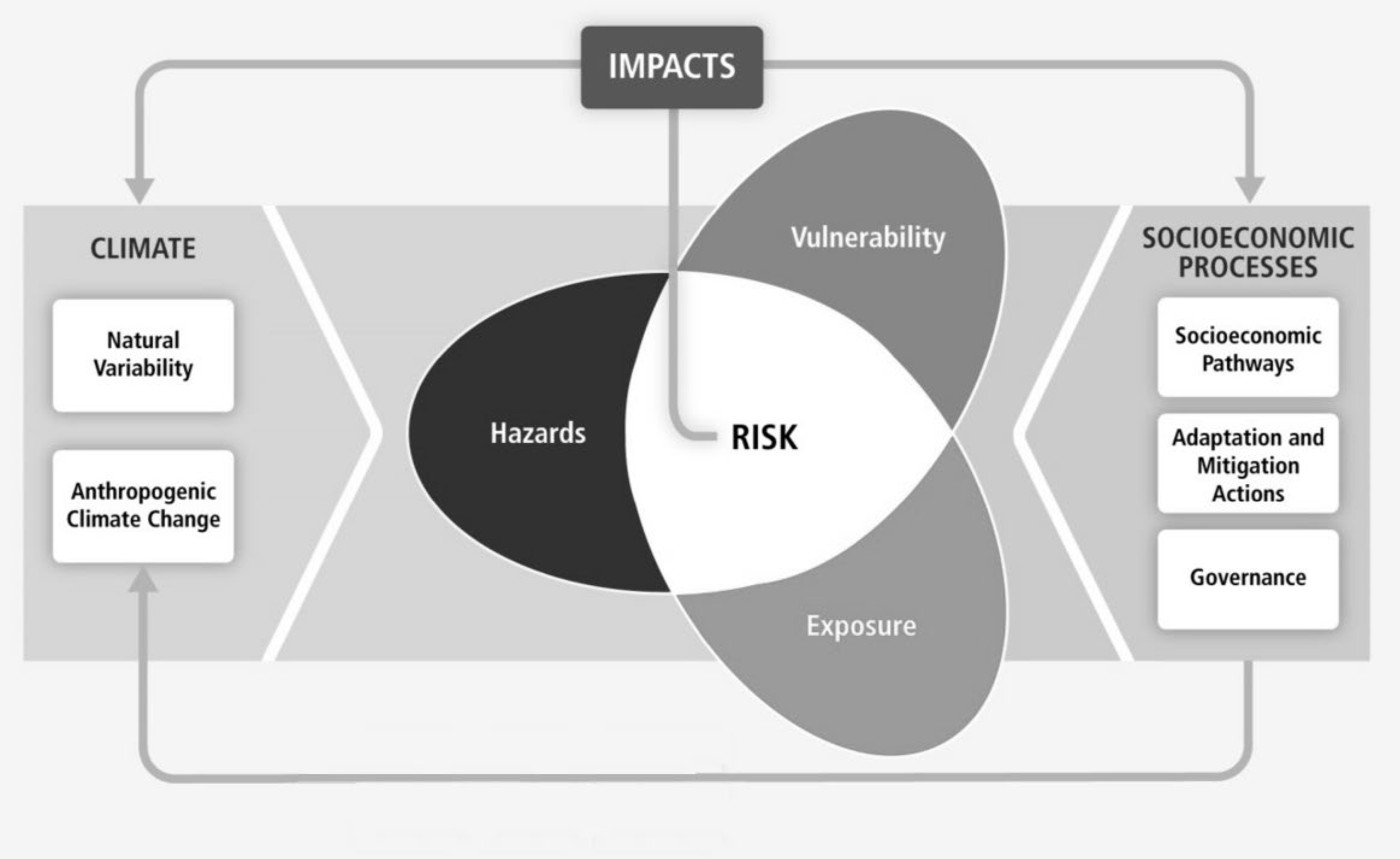
Fisher, J. A. D., Frank, K. T., Belgrano, A. (2015)

Linking the EU CFP, MSFD and the 30x30 Biodiversity targets

- Important to consider the MSFD Descriptor D3 commercial fish and shellfish
- MSFD Descriptor D3 ‘ Populations are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock’
- For the MSFD D3 good environmental status (GES) the CFP indicators for fishing mortality (F) and the spawning stock biomass (SSB) are currenlty used.
- The CFP and MSFD neetd to be linked and support the achievement of the 30x30 targets including the integration of MPAs and OECMs.

IPCC SCENARIOS AND CFP

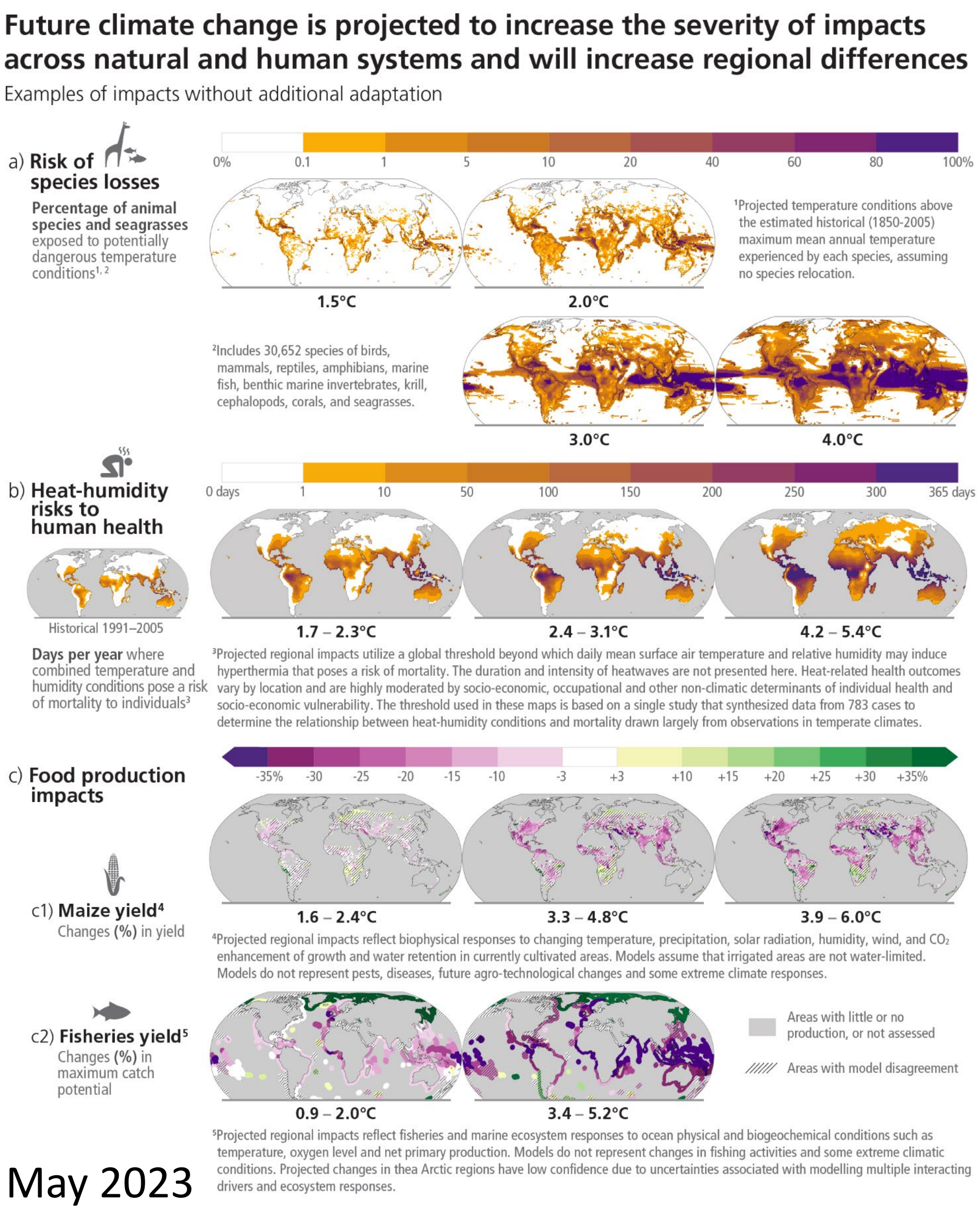
The IPCC conceptual framework for assessment of climate risk (modified from Connelly et al. 2018).



- The functional relationship between the elements of risk, are broken down to reflect the hazard, exposure and vulnerability.
- The risk is also a function of the underlying environmental and socioeconomic context in which climate change occurs.

IPCC 2014

Bartolino et al., 2023. Potential future climate change effects on Swedish fish and fishery. (*in press*)



(a) Risks of species losses as indicated by the percentage of assessed species exposed to potentially dangerous temperature conditions, as defined by conditions beyond the estimated historical (1850-2005)maximum mean annual temperature experienced by each species, at GWLs of 1.5oC, 2oC,3oC and 4oC. Underpinning projections of temperature are from 21 Earth system models and do not consider extreme events impacting ecosystems such as the Arctic.

(c2) Change in maximum fisheries catch potential by 2081–2099 relative to 1986– 2005 at projected GWLs of 0.9°C– 2.0°C (1.5°C) and 3.4°C– 5.2°C (4.3°C). GWLs by 2081– 2100 under RCP2.6 and RCP8.5. Hatching indicates where the two climate-fisheries models disagree in the direction of change. Large relative changes in low yielding regions may correspond to small absolute changes. Biodiversity and fisheries in Antarctica were not analysed due to data limitations. Food security is also affected by crop and fishery failures not presented here.{3.1.2, Figure 3.2, Cross-Section Box.2 } (Box SPM.1).

IPCC-LVIII/Doc. 4 (19.III.2023)Agenda Item: 3

Fisheries and Marine Ecosystem Model Intercomparison Project (Fish-MIP)

nature climate change

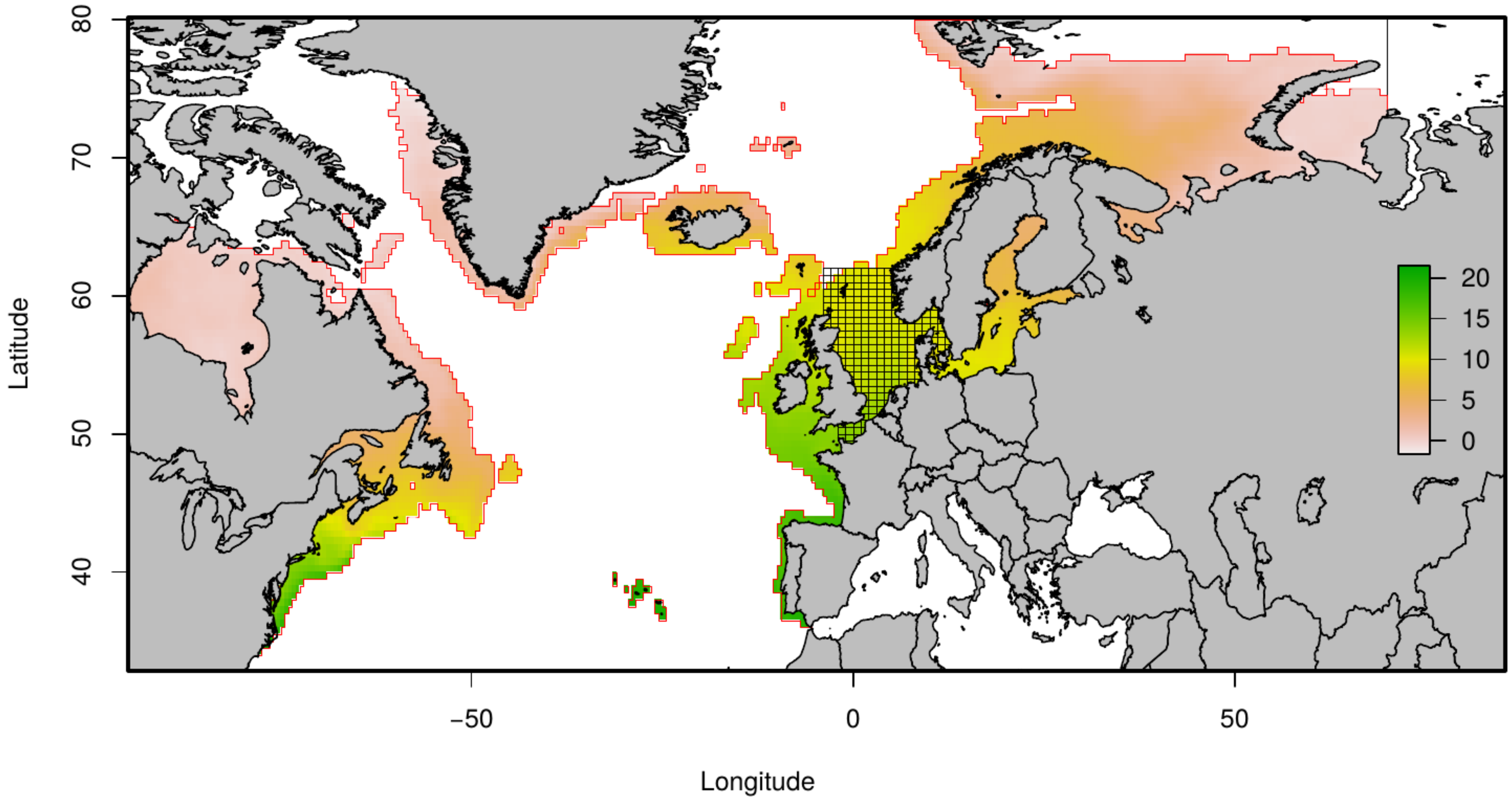
Articles

https://doi.org/10.1038/s41558-021-01173-9

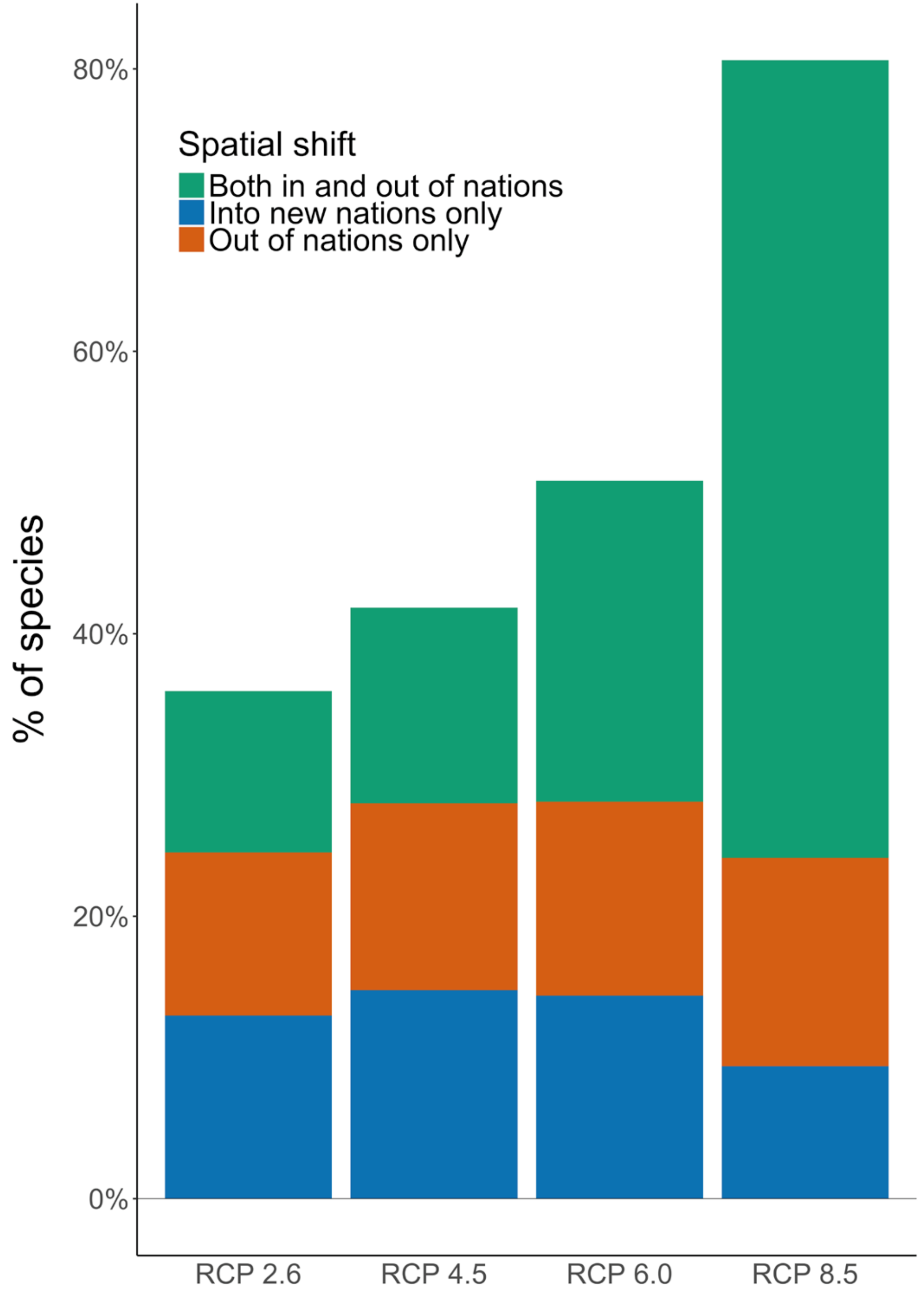
Next-generation ensemble projections reveal higher climate risks for marine ecosystems

Derek T. Tittensor, et al., 2021

Thermal Safety Margin (TSM) for Herring



Bartolino et al., 2023. Potential future climate change effects on Swedish fish and fishery. (*in press*)



Species Spatial Shift

Percentage of species stocks that move into, out of, or both into and out of one or more countries' EEZs by 2100 for each RCP.

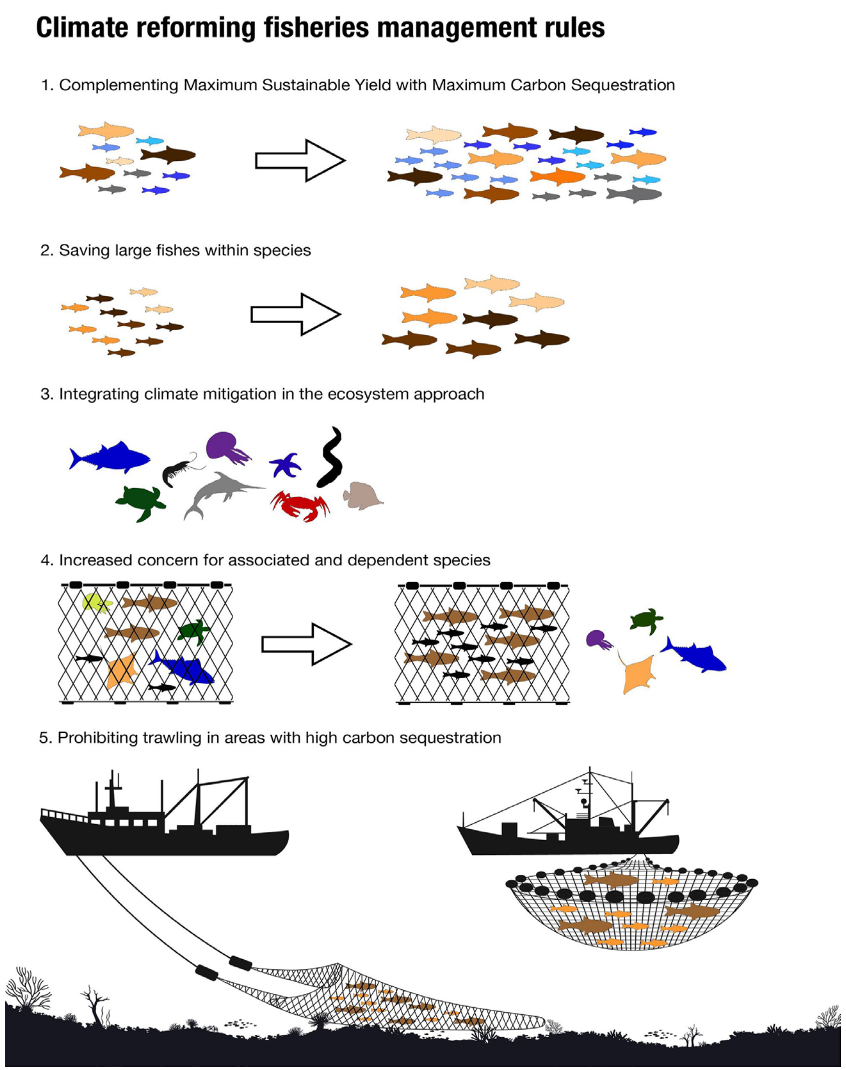
From: Gaines et al., Sci. Adv. 2018; 4 : eaao1378 29 August 2018

PERSPECTIVE

- Although many aspects of climate-based fisheries management remain to be explored, it appears clear that this would imply allowing stocks to recover to maintain a larger amount of biomass, increasing conservation measures for species particularly efficient in providing negative emissions, differentiation of fisheries within species as well as a new approach to ecosystem management.

Krabbe et al., 2022

Perspective



Krabbe N, Langlet D, Belgrano A and Villasante S (2022) Reforming International Fisheries Law Can Increase Blue Carbon Sequestration. Front. Mar. Sci. 9:800972. doi: 10.3389/fmars.2022.800972

CHALLENGES and ACTIONS

- The CFP could account for climate change impacts by targeting smaller fishing mortality then F_{msy} for moving towards a more sustainable fisheries management. (Travers-Trolet M, et al. 2020).

- The MSY concept needs to be reformed to set biomass at a level above MSY; $>B_{msy}$, where B_{msy}, is the biomass that would provide the highest long-term average catch. (Mariani et al., 2020).

- Understanding the trade-offs between conservation and management in view of the 30x30 biodiversity targets including the integration of MPAs and OECMs, and the contribution of SSF to sustainable development.

FAO, Duke University & WorldFish. 2023. Illuminating Hidden Harvests – The contributions of small-scale fisheries to sustainable development. Rome. https://doi.org/10.4060/cc4576en

THANK YOU!