2024-03-07

mNCEA policy brief - Plenty more fish in the sea? Counting the cost of climate change on marine Natural Capital

Atkinson, A

https://doi.org/10.24382/0bn8-x155
Plymouth Marine Laboratory

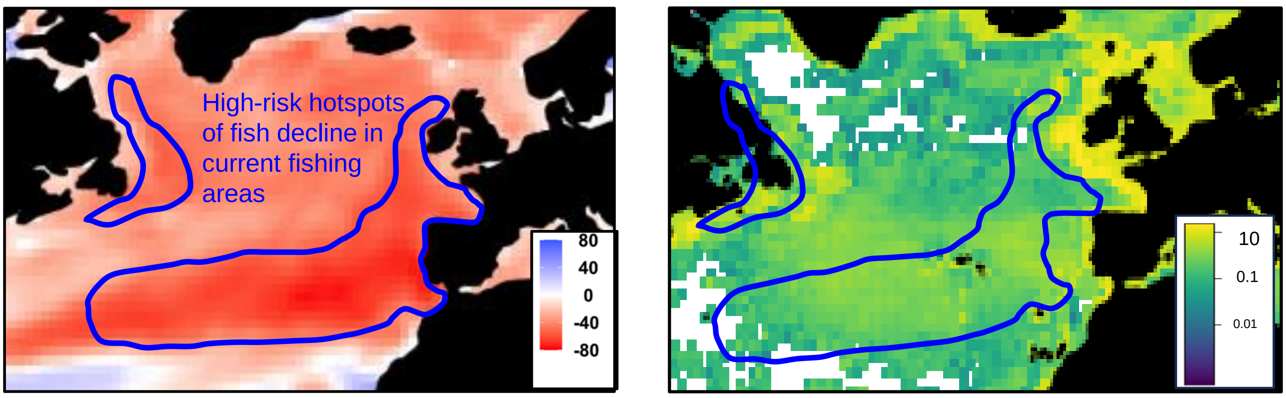
Please cite as: Atkinson, A., E. Bresnan, M. Devlin, M. Faith, M. Holland, A. McQuatters-Gollop, P. Tett and M. Best (2024). mNCEA policy brief - Plenty more fish in the sea? Counting the cost of climate change on marine Natural Capital. Defra mNCEA Programme - Pelagic Natural Capital. Plymouth, UK, Plymouth Marine Laboratory. https://doi.org/10.24382/0bn8-x155.

Plenty more fish in the sea? Counting the cost of climate change on marine Natural Capital

Defra Briefing Report from Pelagic Habitats Expert Group

- Plankton form the foundation of commercially-valuable food chains to fish
- Warming, stratification and reduced nutrient supply has already reduced plankton stocks
- Reduced phytoplankton also means less efficient food chains
- Even a modest (16-26%) continued decline in phytoplankton will magnify into a 38-55% decline in harvestable fish across the north Atlantic
- Hotspots of this future decline in fish are in present-day fishing grounds
- This risk-mapping approach provides a forward look for spatial protection and management

Projected % change in fish biomass (to 2099) | Present-day fishing intensity (h km^{-2}; 2012-2016)



NCEA Natural Capital and Ecosystem Assessment

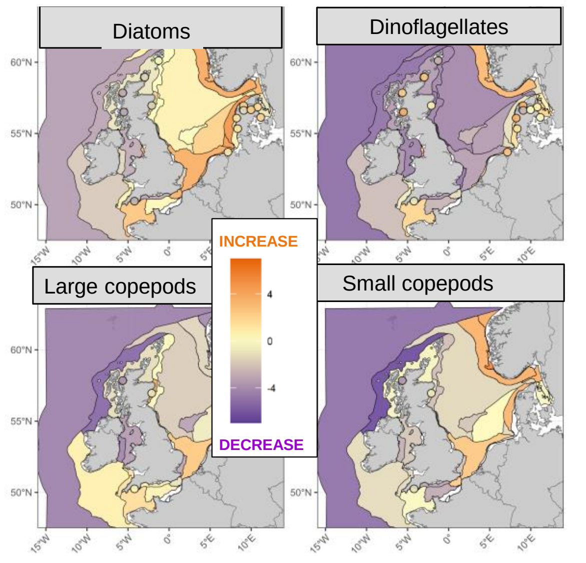
Pelagic Natural Capital Map

UK Pelagic Habitats Expert Group

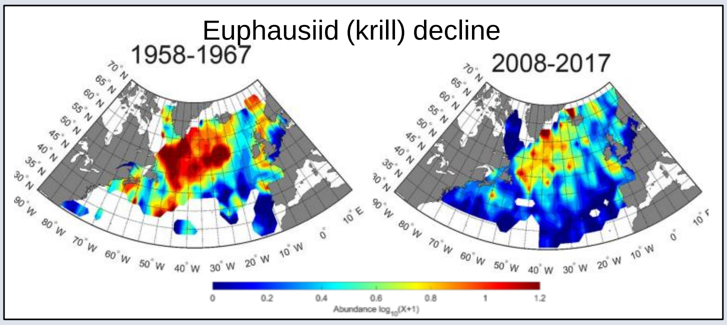
Cardiff University · Prifysgol Caerdydd · University of Plymouth · PML Plymouth Marine Laboratory · Newcastle University · SAMS Scottish Association for Marine Science · Marine Biological Association · Environment Agency · Cefas · Scottish Government Riaghaltas na h-Alba · Cyfoeth Naturiol Cymru Natural Resources Wales · Isle of Man Government · afbi Agri-Food & Biosciences Institute

https://planktonandpeople.org/

Box 1. Decline in food chain supporting fish

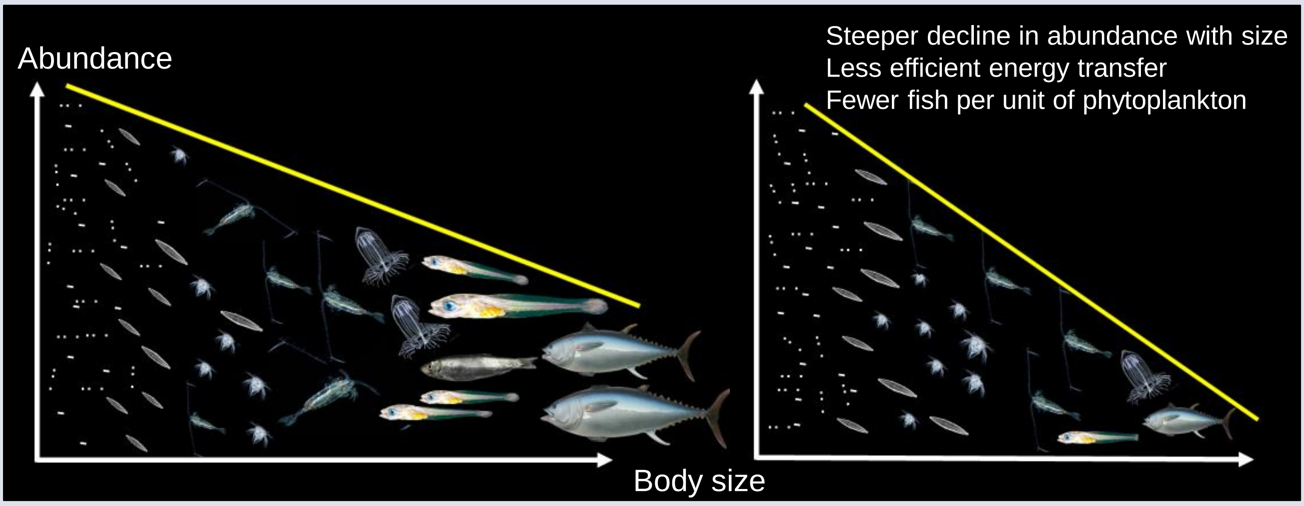


Long-term (30 plus year) data from both fixed-point monitoring stations and from the Continuous Plankton Recorder (CPR) survey are revealing a major decline in key plankton taxa that are traditionally considered to support productive fisheries. Declining plankton include diatoms, dinoflagellates, copepods and euphausiids (krill). Declines are strongest west of the UK and may coincide with increasing oceanic nutrient stress, enhancing the summer dominance of tiny, nutritionally poor picoplankton.



Work by the Pelagic Habitats Expert Group (PHEG) and others has taken both a taxonomic approach (Box 1) and a size-based approach (Box 2), where taxonomic identity is disregarded. The taxonomic approach shows declines in the traditional "textbook" food webs to pelagic fish, particularly to the west of the UK.

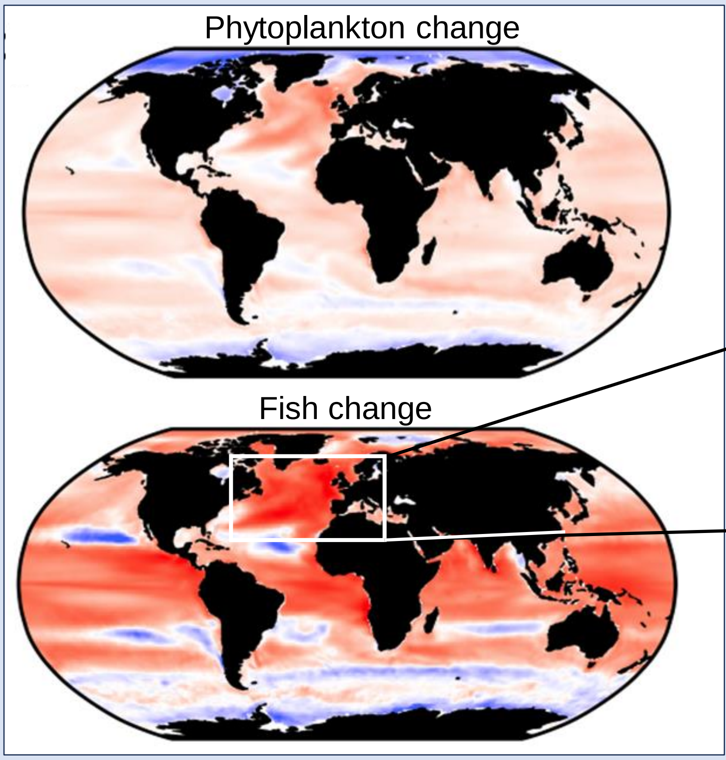
Box 2. The decline in plankton also means less efficient energy flow to fish



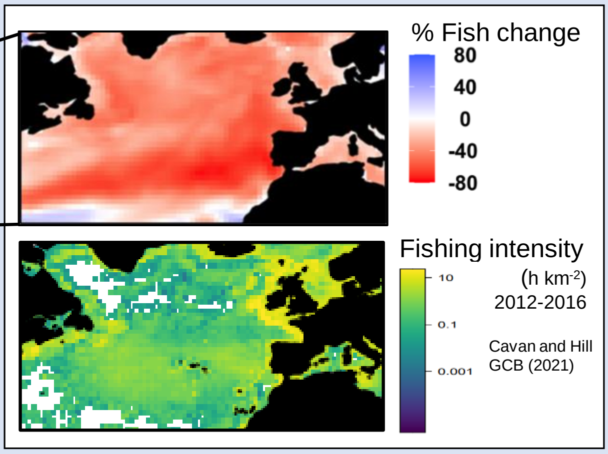
Body size dictates the pace of processes ranging in scale from cell to ecosystem. The decline in total abundance or biomass among increasingly larger pelagic organisms is known as size spectra. The slope of this decline neatly measures the efficiency with which microscopic algae at the base of the food web are transferred to big predators such as tuna. We compiled the slope of this decline in 40 ecosystems around the globe and found that the slope was not related to temperature as many have suggested. Instead, it was related – and strongly – to the nutrient status of the system, proxied by phytoplankton concentration. As phytoplankton declines (as it has in the NE Atlantic), less fish can be supported per unit of phytoplankton

The approach based on size structure is complementary to the taxonomic approach. Here, the rates of decline in abundance or total biomass from small to large species provide a simple, measurable index for the efficiency of energy transfer through marine ecosystems. There are no suitable long time-series of these size spectra (from tiny picoplankton up to fish), so instead we examined a suite of ecosystems that varied in their nutrient status to understand what drives the size spectrum slopes. We found that the structure of the base of the food web (i.e. Chlorophyll-*a* concentration, driven by nutrient status) was the overriding driver of this inefficiency. By calculating the efficiency of energy transfer based on phytoplankton concentration, we can gauge the supportable biomass of fish, based on projected end-of-century changes in phytoplankton from earth system models. (Box 3). Based on these models we project a 38-55% decline in biomass of fish across the North Atlantic and NW European shelf (30°-60°N, 70°W-10°E). The strength of these declines is sensitive to the extent of the projected declines in phytoplankton, and this varies greatly between models. Crucially, the biggest projected declines are where present-day fishing is most concentrated.

Box 3. Projected declines in phytoplankton are amplified in fish, especially in fishing hotspots



In model projections of phytoplankton change from recent past to the end of the century, there will be modest decline of the bottom of the food chain at lower latitudes. This is due to global warming increasing stratification, cutting the nutrient supply to sunlit waters. Based on our results from a compilation of size structure data from globally distributed ecosystems, the supportable biomass of fish will decline much more, by 38-55% across the north Atlantic. UK and NE Atlantic waters are heavily fished but are a hotspot of this projected change.



FAQs

- “Isn’t temperature also directly affecting zooplankton and fish, for example shifting their range, seasonal timing (phenology) and adult body size?” Yes, and studies show that warming reduces body size, affects phenology and shifts species ranges poleward. But this doesn’t fully explain what we are seeing. The changes are too large scale and big to be explained just by shifts in range, body size, or phenology.
- “I thought excess nutrients from eutrophication were bad – but here too few nutrients seems bad?” It is a matter of scale. Large inputs from land can lead to inshore nutrient imbalances, or eutrophication. Nutrient starvation, as we have described here, occurs across broad expanses of ocean, far removed from coastal influences. Nutrient starvation in this case is caused by warming which promotes stratification of the water column, cutting nutrient re-supply from below.
- These suggested declines in fish biomass are from very indirect sources like size structure data – why can’t we simply measure changes in fish? There are no time-series of all fish species over such large scales, and for exploited fish we cannot easily separate effects of fishing and climate change. Size-based approaches give a fresh angle: by applying ecological principles we can estimate the carrying capacity of fish based on the quantity of plankton available to support them.
- Surely isn’t the future carrying capacity of fish (and turnover of fish which is more important for fisheries management) better projected from various food web models? Admittedly, size spectra tell us nothing about fish turnover, but their biomass is a major part of production and size-based approaches offers an empirical alternative to modelling. The fact that the various food web models disagree widely on trends in fish shows that we need a fresh and independent approach.

Atkinson A, Rossberg AG, Gaedke U, Sprules G, Heneghan RF, Batziakas S, Grigoratou M, Fileman E, Schmidt K, Frangoulis C (2014) Steeper size spectra with decreasing phytoplankton biomass indicate strong trophic amplification and future fish declines. *Nature Communications,* https://doi.org/10.1038/s41467-023-44406-5

Capuzzo E, Lynam CP, Barry J, Stephens D, Forster RM, Greenwood N, McQuatters-Gollop A, Silva T, van Leeuwen SM, Engelhard GH (2018). A decline in primary production in the North Sea over 25 years, associated with reductions in zooplankton abundance and fish stock recruitment. *Global Change Biology*, https://doi.org/10.1111/gcb.13916

Holland MM, Louchart A, Artigas LF, Ostle C, Atkinson A., Rombouts I, Graves CA., Devlin M, Heyden B., Machairopoulou M. Bresnan E (2023) Major declines in NE Atlantic plankton contrast with more stable populations in the rapidly warming North Sea. *Science of the Total Environment,* https://doi.org/10.1016/j.scitotenv.2023.165505

Edwards M, Hélaouët P, Goberville E, Lindley A, Tarling, GA, Burrows MT, Atkinson A (2021) North Atlantic warming over six decades drives decreases in krill abundance with no associated range shift. *Communications Biology*, https://doi.org/10.1038/s42003-021-02159-1

Schmidt K, Birchill AJ, Atkinson A, Brewin RJW, Clark JR, Hickman AE, Johns DG, Lohan MC, Milne A, Pardo S, Polimene L, Smyth TJ, Tarran GA, Widdicombe CE, Woodward EMS, Ussher SJ (2020) Increasing picocyanobacterial success in shelf waters contributes to long-term food web degradation. *Global Change Biology,* https://doi.org/10.1111/gcb.15161