# Mapping the climate risk for European fisheries

Malin L. Pinsky[a,1]

With fires, floods, storms surges, and heatwaves becoming dismayingly common because of climate change, how can societies adapt to these and further changes? In this context, fisheries have emerged as the proverbial canary in the coalmine and an important test case for the rest of society. The reason is, in part, because the success or failure of fisheries and the communities supported by them is deeply entwined with the state of ocean ecosystems, and because ocean life is often responding faster and more dramatically to the impacts of climate change than are ecosystems on land. Fisheries are incredibly diverse, however, and a major challenge is to understand where to target adaptation efforts. In their paper, Payne et al. (1) provide an especially detailed social–ecological roadmap by examining climate risk to fisheries in Europe.

European fisheries provide fascinating examples for climate adaptation. From a climate risk perspective, these fisheries have long been overlooked, in part because European countries rely relatively little on fisheries for food, jobs, or economic value (2). However, fisheries play an outsize role in European society, far beyond their purely utilitarian role in food security, employment, or national economies. This importance was illustrated not least by the fact that fisheries were one of the final sticking points in Brexit negotiations. A subsequent dispute over fishing rights around the island of Jersey quickly escalated, with French and English warships deployed to the area in May 2021. Earlier this century, a dispute over mackerel between the European Union (EU), Iceland, and other countries that has been linked to climate impacts subsequently spilled over into a trade war (3). European fisheries encompass an impressive diversity, from subtropical to Arctic ecosystems and from fleets of small artisanal boats to a 144-m supertrawler. Although much of the climate adaptation attention has rightly focused on developing countries with limited resources, it has become increasingly clear that all countries will face serious challenges.

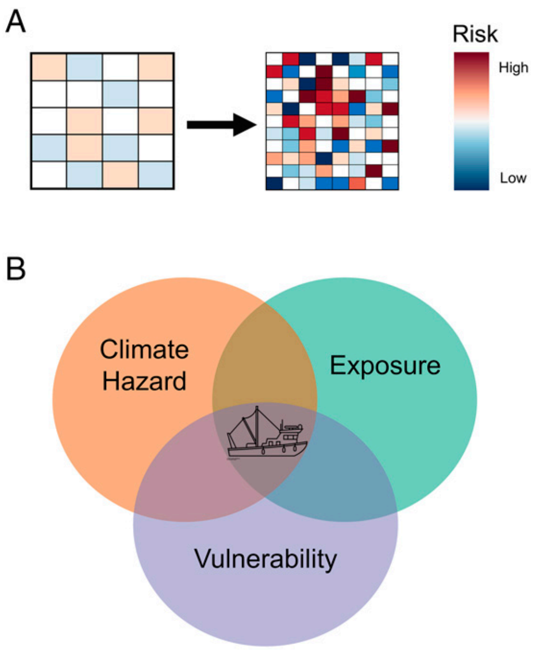


**Fig. 1. (*A*) Climate risk assessments at finer spatial scales (*Right*) can reveal heterogeneity and substantially more extreme risks for particular regions or groups that would not be visible in coarse assessments (*Left*). (*B*) Climate risk can be defined as the intersection of high climate hazards, high exposure to those hazards, and high vulnerability (i.e., low capacity for adapting to climate hazards). Fishing boat by Martin LeBreton from the Noun Project, which is licensed under CC BY 4.0.**

A key lesson from the paper by Payne et al. (1) is the importance of fine-scale climate risk assessments well below the national level. Despite low national climate risk in the United Kingdom and Spain, certain areas in northern England and fleets in Spain may face some of the largest risks of any region and fleet across Europe. Just as climate projections are finding more utility as they are downscaled to the spatial and temporal scales of organisms and human experience, so will climate risk assessments find

[a]Department of Ecology, Evolution, and Natural Resources, Rutgers University, New Brunswick, NJ 08901
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[1]Email: malin.pinsky@rutgers.edu.
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more utility at finer scales as well (Fig. 1*A*). Coarse averages across space hide the diversity of risk levels faced by coastal communities and fishing fleets that are otherwise geographically proximate. The ongoing challenge is to find or collect relevant data at these finer spatial scales, which partly explains why previous assessments have focused on either narrow geographic regions or coarse spatial grains.

The reasons for elevated climate risk also differ substantially among regions and fishing fleets, and these differences suggest different foci for future climate adaptation efforts. Coastal regions in England appear to face high climate risk because they harvest many species that are already close to their thermal limits and therefore more likely to decline from further warming. Adaptation measures could, for example, help fisheries transition to new species likely to benefit from climate change in those regions. New permitting regimes, new fishing gear, and new cooperative agreements with adjacent fisheries managers (especially the EU) may be needed, particularly given that Europe largely relies on the principle of relative stability. Under relative stability, different countries are allocated quotas based on their relative catches of different species in 1973–1978, even if the species have shifted to new regions. Renegotiating such agreements is anything but easy, although side payments and other mechanisms to facilitate cooperation can help (4).

In contrast to this ecological source of risk, areas in southeast Europe like Romania and Croatia were assessed to have high risk primarily because of economic and social factors. These areas appear to have fewer economic resources and rely on a small number of species that run the risk of all collapsing together. Adaptation efforts could include dedicated climate adaptation funding or efforts to diversify the fisheries across a wider range of target species.

Small fishing vessels in Europe also stood out as being at high risk from climate change, a pattern that has appeared frequently in the adaptation literature. Over 90% of fishing vessels globally are small scale, and more than 120 million people around the world are involved in or supported by these fisheries (5). The low profitability of small-scale fisheries makes them vulnerable to climate change, although small-scale fleets that catch a diversity of species may be less exposed to climate impacts. In support of this idea, more-diverse small-scale fishing communities largely persisted during a period of rapid ocean warming in the United States, while less diverse fishing communities largely disappeared (6).

These different pathways to climate risk reflect the way in which the Intergovernmental Panel on Climate Change defines the term as a combination of hazard, exposure, and vulnerability (7) (Fig. 1*B*). Climate hazard refers to the possible occurrence of a physical event with adverse consequences. Exposure quantifies the human or other resources located where the climate hazard may occur. Vulnerability reflects the propensity for adverse consequences to occur if a resource is exposed to a climate hazard. Ideally, these steps in calculating risk would be measured as probabilities and magnitudes of various hazards, the value of resources exposed to those hazards, and the probability of damage of a given magnitude given these exposures. However, such quantitative risk assessments remain difficult in practice, leaving substantial room for and utility of qualitative approaches like that used by Payne et al. (1). In this paper, they defined intuitive although necessarily incomplete indices for each risk component. Hazard was defined as being higher for target species with longer lifespans and narrow habitat requirements, and as higher in populations that inhabited waters closer to the species' highest observed habitat temperatures. Exposure was higher for fisheries that caught only or primarily one or a few species. Vulnerability was higher for regions with low GDP per capita or fleets with low profitability, under the logic that these segments of society would have fewer resources to fund adaptations like new gear or new permits.

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A key recommendation from this paper (1) is that climate risk can be reduced for many fisheries through greater diversification across a wider variety of target species. This inverse risk–diversity relationship is assumed by Payne et al., supported by abundant evidence from fisheries (6, 8, 9) and from complex adaptive system theory more generally (10). When target species respond differently to climate change or extreme events, this response diversity can allow some species to continue supporting a fishery, even while other species decline. Response diversity can be inferred, to some degree, from geographic factors [i.e., poleward populations are more likely to increase with warming, and low-latitude populations are more likely to decline (11)], but the inherent complexity of ecosystems also implies that not all responses will be predictable and that diversity itself may be a more useful metric. Promoting diversity in fisheries will require a variety of economic, governance, and social incentives, as well as a careful understanding of barriers to diversification like potential tradeoffs between profitability and diversity.

In terms of future research, a few areas stand out. First, climate risk for fisheries depends not only on the potential for some species to decline but also on the potential for increases in other species to offset negative hazards. Understanding how, when, and where such mitigating climate impacts might occur will require careful investigation, in part because synchrony and the potential for lagged responses among different species also shape their social consequences. Second, moving toward quantitative risk assessments will require mechanistic models that consider economic, social, and ecological processes to integrate hazards, exposure, and vulnerability. Identifying models that are complex enough to be realistic but simple enough to parameterize with available data will be a challenge. Benefits of mechanistic models can include a better understanding of nonlinear responses, cumulative impacts, and the potential for tipping points in fisheries. Finally, expanding the detailed and fine-scale approach of Payne et al. (1) to other regions will be highly useful, but data availabilities in different regions will likely require different proxy data and approaches.

More important, however, are the next steps for society to begin adapting fisheries to climate change. Scenario analysis and other tools can be a key first step to envision potential futures for each fishery, followed closely by the development of climate adaptation plans. Transitioning to new target species, more-flexible allocation methods, and greater cooperation among institutions are likely to play important roles. Given the timescales of human decision-making, near-term (annual to decadal) forecasts of climate impacts could also help motivate action. However, there will not be one magic solution for all fisheries, but rather a diversity of tools, some of which will be useful in each case. The risk of catastrophic collapse increases as ocean ecosystems are pushed farther from historical environments, which emphasizes the benefits of mitigating further climate change (e.g., less than 1.5 °C warming). Current institutions are built upon an implicit assumption that fish of the future will largely be the same as fish of the past, despite now overwhelming counterevidence. Adapting these complex institutions will not be easy, but risk assessments that help target adaptation efforts to those areas most in need are a critical first step.


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