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Preview

Structuring the Discussion on the Multiple Threats of Climate Change to Fisheries around Impact Pathways and Adaptation Pathways

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https://doi.org/10.1016/j.oneear.2020.05.017

Climate change is threatening the fisheries on which communities depend. In this issue of *One Earth*, Ojea et al. describe the impacts of species range shifts and discuss possible adaptation pathways and policy solutions. However, climate change brings multiple threats to fisheries, so framing the discussion on adaptation options is critical.

Climate change is bringing a multitude of threats to fisheries across the globe, which necessitates planning at all levels of decision making to avoid the worst impacts on the livelihoods of coastal communities.[1] Species range shifts, driven by changes in environmental conditions, could lead to significant changes in the distribution of future catch potential.[2] The contraction, expansion, or fragmentation of the geographic distribution of species could lead to ecological changes driven by different trophic interactions, the introduction of invasive species, or even ecosystem phase shifts, which could disrupt food webs and lower catch potential. The shift in the distribution of targeted species could lower revenues and affect the livelihood of fishers, particularly for coastal small-scale fisheries and highly specialized fisheries that are more dependent on marine resources and have a lower capacity to cope.

Adaptation planning builds on the assessment of species range shifts or societal vulnerability to implement action that will increase the fishery system's resilience, lower the system's exposure to change, or decrease its vulnerability to future impacts. Such actions could include reforming the management of overfished stocks, modifying fleet capacity or fleet characteristics to target a different species, or adapting governance to resolve legal disputes. Although adaptation planning will be needed everywhere, like many other climate-change impacts, species range shifts will affect areas differently. Geographical disparities will exacerbate inequalities and disqualify a one-size-fits-all adaptation planning strategy. Species range shifts will mean losing species at low latitudes for species that cannot adapt to increasing temperatures, and as a consequence, countries within the tropics, already the most dependent on fish and fisheries, will experience mostly negative impacts. Countries at higher latitudes will also experience a change in the geographic range of species but could see a gain in fisheries' productivity as a result of other climate processes,[3] reinforcing inequalities across countries. Shifting species ranges could therefore create or strengthen local and international conflicts over access to moving stocks. What is needed to inform adaptation planning is to characterize the possible impacts of ecological changes and the possibilities of societal responses to them.

In their Perspective in this issue of *One Earth*, Ojea et al. bring the impacts of species range shifts and adaptation pathways together.[4] They review the different streams of evidence in the literature on species range shifts and the resulting changes in marine ecosystems. They then discuss how ecosystem changes could lead to impacts on fisheries, economies, and societies overall. They discuss possible actions to maintain, cope, adapt, or transform the fishery system in order to respond to climate-change-induced species range shifts at the local, collective, and institutional scales, as well as the risks associated with each action. Finally, they structure their discussion on adaptation and the risks associated with maladaptation into a set of policies with the intention of promoting "equitable resilience." Ojea et al.'s Perspective is a great starting point for anyone planning a response to the impacts of species range shifts.

The structuration of different adaptation pathways has scientific implications for the integration of response mechanisms in modeling the work of climate impacts on fisheries (such as in Barange et al.[3]). It paves the way for new research on trade-offs and synergies of adaptation responses. It will guide social science in its inquiry of determinants of adaptive capacity at different scales given that these determinants have been conceptualized at the community level[5] but not yet at higher scales. In addition, evidence suggests that there are factors influencing the adaptive capacity of fishing communities to cope with change (e.g., Rogers et al.[6]), but not to adapt or transform their system to change, which probably requires other types of capacities. This Perspective therefore also paves the way for the inquiry of determinants of adaptive capacity across types of responses. Listing possible responses at different scales of intervention has policy implications because it provides structure and building blocks for adaptation planning. Discussions around transformative change have remained mostly conceptual; Ojea et al.'s Perspective attempts to identify transformative actions to deal

with the impacts of species range shifts. Finally, it could contribute to the design of policy tools for managing fisheries, including marine spatial planning and bilateral and multilateral treaties, such as the ongoing negotiations on biodiversity beyond national jurisdiction.

However, climate change will not only affect fisheries through the shift in target species ranges. Climate change is also expected to bring more intense and frequent extreme events. Contrary to species range shifts, extreme events are fast events, such as storms that prevent fishery activities and destroy coastal infrastructures and ecosystems.[7] Extreme events also include heat waves (which affect the health and working conditions of vulnerable coastal populations) and coral bleaching events (which can cause mass mortality of corals, thus affecting the marine food webs that depend on them).[8]

Ojea et al.'s clear conceptual figures describing impact pathways and adaptation pathways provide a solid framework for discussing possible actions and informing the adaptation of fisheries to extreme events, a process that requires the involvement of a variety of actors. What is less straightforward is discussing the implications of both species range shifts and extreme events occurring in terms of adaptation planning. In analyses aimed at informing climate-change adaptation, there is a tension between complexification and simplification.

On the one hand, increased complexification in modeling the climate impacts on fisheries is made available by scientific advances. This is seen as a way to get more robust estimates, understand feedback loops and ecological thresholds, and better predict future states of fisheries. But it is difficult to communicate such modeling work to the diverse audience of policymakers and managers responsible for the design and implementation of adaptation plans. These exercises are informative at the global or regional level, but implementing them becomes harder at the national and sub-national levels, particularly so in low latitudes where capacity is limited and data are scarce. On the other hand, focusing on specific effects such as species range shifts can be seen as a simplification of the complex challenges facing fisheries. These heuristics provide an important setting for discussing adaptation planning by detailing specific attributes and proposing adaptation responses tailored to the issue. Contrary to the idea of integrating more complexity in modeling, the simplification of climate-change effects into heuristics can be used in addition to other streams of knowledge for producing transdisciplinary collaborations.[9]

When we discuss adaptation to multiple threats, an important element is to understand whether an action geared to increase resilience toward one effect of climate change could lower the resilience to other effects. Here again, Ojea et al.'s Perspective helps to channel information. Accounting for multiple threats could either increase the magnitude of the impact pathways identified or diversify the pathways through which climate effects will affect fisheries, the economy, and society.

If the magnitude increases, the appropriate response could be to move up the type of response linearly from maintaining to coping, adapting, and finally transforming the system. If the impact pathways change when more climate effects are included, this linear step assumption does not hold. For example, when an increase in cyclone frequency is forecast, a coping action such as putting in place "temporary shifts to other income sources" is deemed most appropriate. When a contraction in the range of a targeted species is forecasted, the adaptation action "target new species" is deemed the most appropriate response. But if both threats are forecasted to occur, is the best response to implement both types of actions? Could it be possible that targeting new species by investing in new material actually decreases the fishery's resilience if an extreme event occurs? Should a transformative change, such as "exit the seafood sector," then become the most appropriate course of action? There are several research avenues on informing these difficult choices. A first direction could be to qualitatively assess the synergies and trade-offs between actions to adapt to extreme events and those to adapt to species range shifts. A second direction could be to produce scenarios and decision trees to explore the impact of different choices. A third could be to add a temporal dimension on the possible occurrence of these climate impacts to sequence the implementation of action, thus putting the system in a sustainable path-dependency trajectory of change.[10]

What is certain is that the process of adaptation planning should involve information on both impact pathways and adaptation pathways. As demonstrated by the synthesis of empirical and theoretical evidence in Ojea et al.'s Perspective, one does not directly flow from the other, and complex interactions exist in social-ecological systems' responses to climate change. Every change in components of the social-ecological systems, whether because of an impact or an action, should be an opportunity to learn, test assumptions, and imagine what comes next.

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