Exploited marine biodiversity and climate change

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Climate change is impacting the productivity of marine ecosystems and fisheries, while demand for fish for human consumption is increasing. Fish is the main source of animal protein for one billion people and is one of the most traded renewable resources in the world. Changes in physical and chemical characteristics of seawater affect individual metabolism, species' life cycles, predator-prey relationships, and changes in habitat. Geographic distributions of fish (migration rate towards the poles is 72.0 ± 13.5 km/decade) and ecosystem dynamics could undergo profound disruption in the coming decades, impacting fisheries globally and jeopardizing food security in many southern countries. Maintaining healthy, productive marine ecosystems is a critical issue.

CHALLENGES FACING MARINE FISHERIES

Climate change is affecting marine ecosystem productivity and impacting fisheries. This sector represents the last human activity exploiting, on an industrial scale, a wild resource that is sensitive to environmental fluctuations. Population growth and changes in eating habits have led to increasing demand for fish for human consumption. Fish is now the main source of animal protein for one billion people worldwide. It is also one of the most traded global renewable resources: 28 million tonnes of marine fish are destined for US, European and Japanese markets, which together account for 35% of world catches, with over two-thirds provided from southern hemisphere countries (Swartz *et al.*, 2010).

In a context of climate change, fish geographic distribution and ecosystem dynamics are expected to undergo profound disruption in the coming decades, thus affecting fisheries worldwide, and jeopardizing food security in many countries of the southern hemisphere (Lam *et al.*, 2012).

IMPACTS OF CLIMATE CHANGE ON MARINE BIODIVERSITY

Marine life is affected by variations in water temperature, oxygen concentrations, acidification, the severity of extreme climate events and ocean biogeochemical properties. These changes have either direct or indirect effects on individual metabolism (growth, respiration, etc.), species' life cycles, predator-prey relationships and changes in habitat.

They affect both the individual level, and the interactions between species and habitats, thus triggering changes in species assemblages, but also in productivity and ecosystem resilience (Goulletquer *et al.*, 2013).

Disturbances are now clearly established across a wide variety of taxonomic groups, ranging from plankton to top predators, and are in line with theoretical approaches to the impact of climate change (Poloczanska, 2014). Beaugrand *et al.* already demonstrated in 2002 that large-scale changes were occurring in the biogeography of calanoid crustaceans in the northeast Atlantic Ocean and European continental seas. Northward shifts of warm-water species by more than 10° latitude coinciding with a decrease in the number of cold-water species are related both to the rise in temperature in the northern hemisphere and to the North Atlantic Oscillation.

Results from a recent global analysis show that changes in phenology, distribution and abundance are overwhelmingly (81%) in line with the expected responses in a context of climate change (Poloczanska, 2013). Today, a large number of biological events concerning maximal phytoplankton and zooplankton abundance, as well as reproduction and migration of invertebrates, fish and seabirds, all take place earlier in the year. Hence, over the past fifty years, spring events have been shifting earlier for many species by an average of 4.4 ± 0.7 days per decade, and summer events by 4.4 ± 1.1 days per decade. Observations show that for all taxonomic groups, albeit with great heterogeneity, the migration rate towards the poles reaches 72.0 ± 13.5 kilometers per decade. Changes in distribution of benthic, pelagic and demersal species can extend up to a thousand kilometers.

These poleward migrations have led to an increase in the number of warm-water species in areas like the Bering Sea, the Barents Sea and the North Sea. The observed modifications in benthic fish and shellfish distribution with latitude and depth can be mainly explained by changes in sea temperature (Pinsky *et al.*, 2013). The migration rates recorded in the marine environment appear to be faster than those observed in the terrestrial environment.

IMPACT ON FISHERIES AND GLOBAL FOOD SECURITY

Marine fish and invertebrates respond to ocean warming by changing their distribution areas, usually shifting to higher latitudes and deeper waters (Cheung *et al.*, 2009). The variation in the global catch potential for 1,066 species of marine fish and invertebrates harvested between 2005 and 2055 can be predicted based on different climate change scenarios. According to these studies (Cheung *et al.*, 2009), climate change may cause a large-scale redistribution of the total catch potential, with an average increase of 30 to 70% in high-latitude regions and a decrease of up to 40% in the tropical regions. Among the 20 most important fishing areas of the Exclusive Economic Zone (EEZ) in terms of landings, the EEZ regions with the highest increase in catch potential by 2055 are Norway, Greenland, the United States (Alaska) and Russia (Asia). On the other hand, the EEZ areas with the greatest loss of maximum catch potential include Indonesia, the United States (except Alaska and Hawaii), Chile and China. Many severely affected areas are located in the tropics and are socio-economically vulnerable to these changes.

Further studies, taking into account factors other than ocean temperature, highlight the sensitivity of marine ecosystems to biogeochemical change and the need to include possible hypotheses concerning their biological and ecological effects in impact assessments (Cheung *et al.*, 2011).

Hence, the predictions for the year 2050 regarding the distribution and catch potential of 120 fish and demersal invertebrate species harvested in the North Atlantic show that ocean acidification and decreasing oxygen concentrations could reduce growth performance and lower the estimated catch potential by 20 to 30% (10-year average for 2050 compared to 2005) in comparison with simulations that do not take these disrupting factors into account. In addition, changes in the phytoplankton community structure could also reduce the predicted catch potential by about 10%. All these results highlight the sensitivity of marine ecosystems to biogeochemical changes (Cheung *et al.*, 2011). The observed changes in the species composition of catches between 1970 and 2006 are largely attributable to long-term ocean warming (Cheung *et al.*, 2013). Modifications in the marine environment are expected to continue to generate considerable challenges and costs for human societies worldwide, particularly for developing countries (Hoegh-Guldberg & Bruno, 2010).

HOW CAN WE LIMIT THE IMPACTS OF CLIMATE CHANGE ON MARINE ECOSYSTEMS?

The best way to combat the effects of climate change is to preserve biodiversity and avoid overexploiting certain species. The latter has been recognized as a factor aggravating the impacts of climate change (Perry *et al.*, 2010). The Ecosystem Approach to Fisheries (EAF) reconciles the exploitation and conservation of species, *i.e.* it aims to maintain ecosystem integrity and resilience. The EAF thus contributes to the crucial issue of keeping marine ecosystems healthy and productive, while proposing a new way of considering fish exploitation in a broader context (www.fao.org/fishery/eaf-net).

The role played by Marine Protected Areas (MPAs) in protecting marine habitats and biodiversity, thereby making ecosystems more resilient, is crucial to support efforts to mitigate climate change (Roberts *et al.*, 2017). The need to develop an adaptation policy designed to minimize the impacts of climate change through fishing must become a priority. This will require better anticipation of changes using predictive scenarios (in the sense of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services – IPBES) and implementing public policies to be able to adapt to the changes taking place in marine ecosystems within the framework of the UN 2030 Agenda for Sustainable Development (Euzen *et al.*, 2017). Although the impact of climate change will most of the time remain unavoidable, the adaptation of communities to rapid changes has yet to be understood and assessed, which opens up many opportunities for research on this topic.

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