Exploited Marine Biodiversity and Climate Change

Philippe Cury
(IRD, Sète)

Climate change is affecting the productivity of marine ecosystems and impacts fishing, while the 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 renewable resources most transacted in the world. Changes in physico-chemical characteristics of seawater affect the metabolism of individuals, the life cycles of species, relationships between predators and prey, and modification of habitats. Geographic distributions of fish (displacement rate towards the poles is 72.0 ± 13.5km/decade) and the dynamics of ecosystems could undergo profound disturbances in the coming decades, affecting fisheries globally and jeopardizing food security in many southern countries. The maintenance of healthy and productive marine ecosystems is a critical issue.

THE CHALLENGES IN MARINE FISHERIES

Climate change is affecting the productivity of marine ecosystems with an impact on fisheries. Fisheries represent the last human activity that is exploiting, at an industrial scale, a wild resource that is sensitive to environmental fluctuations. Population growth and changes in food habits have led to an increasing demand for fish for human consumption. Fish has become the main source of animal protein for a billion people worldwide. It is also one of the most traded global renewable resources: 28 million tones 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 it appears that the geographical distribution of fish and ecosystem dynamics are to undergo profound disruptions in the coming decades thus affecting fisheries worldwide, and jeopardizing food security in many countries of the southern hemisphere (Lam *et al.*, 2012).

THE EFFECTS OF CLIMATE CHANGE ON MARINE BIODIVERSITY

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

The disturbances are now clearly established across a wide range of taxonomic groups ranging from plankton to top predators and in agreement with the theoretical approaches regarding 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 accordance with the expected responses in a context of climate change (Poloczanska, 2013). A large number of biological events concerning maximal phytoplankton abundance as well as reproduction and migration of invertebrates, fish and seabirds, all take place earlier in the year. Hence, since the past fifty years, the Spring events have been shifting earlier for many species by an average of 4.4 ± 0.7 days per decade and the summer events by 4.4 ± 1.1 days per decade. Observations show that for all taxonomic groups, but with great heterogeneity, the rate of displacement 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 or the North Sea. The observed modifications in the distribution of benthic fish and shellfish with latitude and depth can be mainly explained by changes in the temperature of the sea (Pinsky *et al.*, 2013). The migration rates recorded in the marine environment appear to be faster than observed in the terrestrial environment.

THE IMPACT ON FISHERIES AND GLOBAL FOOD SECURITY

As mentioned above, fish and marine 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 capture potential for the stock of 1066 species of marine fish and invertebrates exploited between 2005 and 2055 can be predicted according to different climate change scenarios. According to these studies (Cheung *et al.*, 2009), climate change may lead to a large-scale redistribution of the overall catch potential, with an average increase of 30 to 70% in high-latitude regions and a drop reaching 40% in the tropics. Among the 20 most important fishing areas of the Exclusive Economic Zone (EEZ) in terms of landings, ZEE regions with the highest increase in the potential catches in 2055 should be Norway, Greenland, the United States (Alaska) and Russia (Asia). On the contrary, the EEZ areas with the greatest loss of maximum catch potential should include Indonesia, the United States (except Alaska and Hawaii), Chile and China. Many severely affected areas would be located in the tropics and would be socio-economically vulnerable to these changes.

Further studies, taking into account factors other than the temperature of the oceans, highlight the sensitivity of marine ecosystems to biogeochemical change and the need to take into account the 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 catchability of 120 species of fish and demersal invertebrates exploited in the North Atlantic show that ocean acidification and decreasing oxygen concentrations could reduce the growth performance and lower the estimated catch potentials from 20 to 30% (10-year average for 2050 compared to 2005) in comparison with simulations that do not take these disturbing factors into account. In addition, changes in the phytoplankton community structure could also reduce the predicted catch potential by ~ 10%. All these results highlight the sensitivity of marine ecosystems to biogeochemical changes (Cheung *et al.*, 2011).

The observed changes are now noticeable in the species composition of catches between 1970 and 2006 which are largely attributed to global long-term ocean warming (Cheung *et* *al.*, 2013). Modifications in the marine environment should continue to generate considerable challenges and costs for human societies worldwide, particularly for developing countries (Hoegh-Guldberg & Bruno, 2010).

HOW TO LIMIT THE EFFECTS OF CLIMATE CHANGE ON MARINE ECOSYSTEMS?

The best way to fight against the effects of climate change is to preserve biodiversity and avoid overexploitation of certain species. The latter has been admitted as an aggravating factor on the effects of climate change (Perry *et al.*, 2010). An objective of the Ecosystem Approach to Fisheries (EAF) is to reconcile exploitation and conservation of species; in other words it would allow to maintain the integrity and resilience of ecosystems. The EAF contributes to the crucial issue of maintaining marine ecosystems healthy and productive, while proposing a new manner of considering fish exploitation in a broader context (www.fao.org/Fishery/eaf-net). The need to develop an adaptation policy that could minimize the impacts of climate change through fishing must become a priority. This would require better anticipation of changes using predictive scenarios (*sensu* 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. Although the impact of climate change remains most of the time unavoidable, the adaptation of communities to rapid changes are yet to be understood and assessed, thus opening many research perspectives on this subject.

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