Chapter 6.4 Fish Catch Potential in the Open Ocean Under Different Climate Change Projections

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6.4 Fish Catch Potential in the Open Ocean Under Different Climate Change Projections

6.4.1 Summary and Key Messages

The open ocean, for example: the oceanic area beyond the 200 mile Exclusive Economic Zone (EEZ) of maritime countries, will be increasingly impacted by climate change, as will coastal areas of the ocean. These changes are investigated using a bio-climate envelope model capable of reproducing and amplifying the observed poleward migration of fish exploited by fisheries under the IPCC Special Report on Emission Scenario (SRES) A2. The results are an overall predicted reduction of 20 per cent of the potential catch of the open ocean to 2030 and 34 per cent to 2050. The strongest declines of potential catch should occur in the intertropical belt, because increasing stratification will depress primary and secondary production and because no fish will replace those tropical fish that migrate poleward. Declines are also expected in Antarctica, because the life cycle of the currently abundant krill (*Euphausia superba*) is tied to shelf ice, that is expected to melt away.

Key Messages

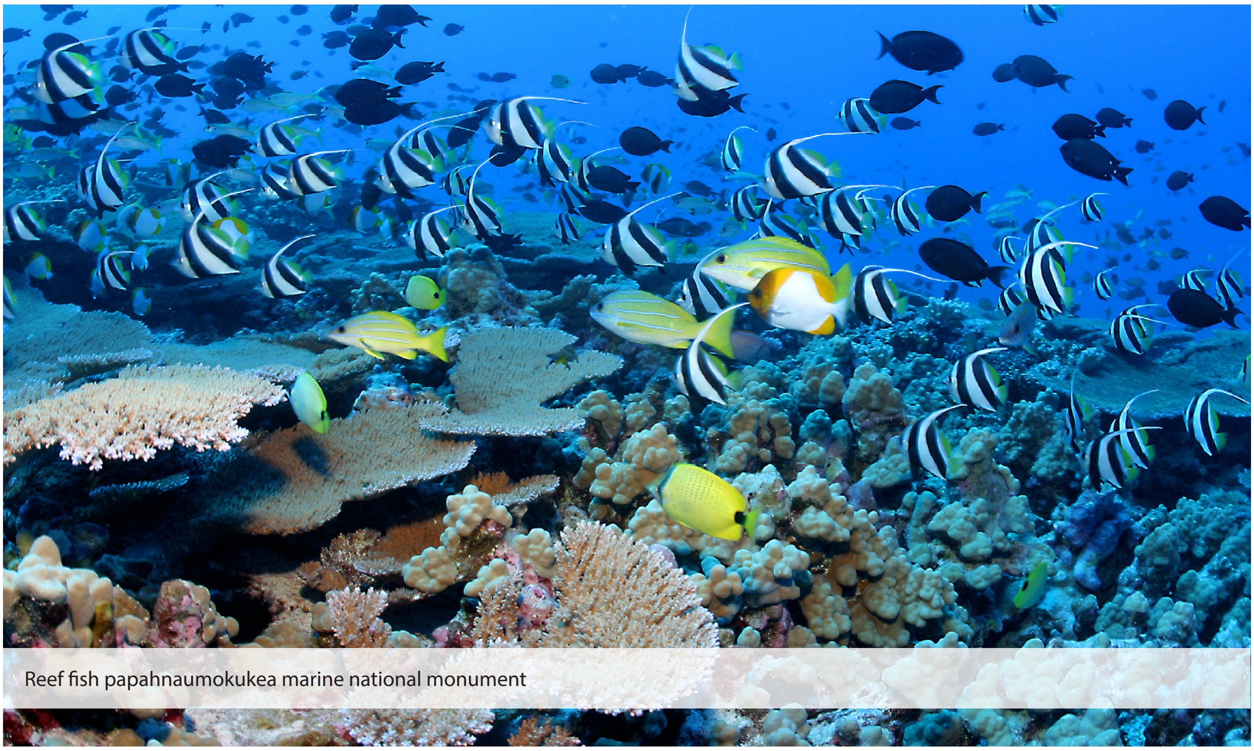
- Future climate change will *likely* have an impact on future fish catch in the open ocean, which may have large implications for the fishing industries, economies and livelihoods of many countries;
- Open ocean potential fish catch is projected to decline by 20 percent by 2030 and by 34 percent by 2050; and
- The greatest declines are projected to occur in the inter-tropical belt and in Antarctica.

Along with other non-climatic factors such as changes in markets, demographics, overexploitation, management and governance regimes, climate change is a major issue that will shape fisheries in the future. Although several studies suggested that management interventions and stressors other than climate changes may have a greater impact on fisheries than climate change in the short term (Eide 2007, Daw et al. 2008), increasing changes in ocean climate still pose a major threat to world fisheries in the long term. Rising water temperatures, as well as related changes in ice cover, salinity, carbon dioxide levels, dissolved oxygen and circulation may intensify shifts in the range of marine species that are already occurring (Polovina 1996, Clark et al. 2003, Drinkwater 2005, Rose 2005, Cheung et al. 2008a; 2013). These may include negative impacts on coral (Graham et al. 2007, Hoegh-Guldberg 2007), a decline in phytoplankton (Boyce et al. 2010), and range change and earlier migration of diadromous species (IPCC 2007). Change in ocean temperatures and primary productivity may cause the poleward shift of distribution boundaries of commercially important marine fishes and shellfish in the world ocean (Cheung et al. 2009, 2013). The combined effects of distribution shift and changes in ocean primary productivity under climate change could lead to global redistribution of maximum potential catch (Cheung et al. 2010). A recent study also showed that warmer temperature may lead to a decrease in maximum body sizes of marine fishes (Cheung et al. 2012). These predicted changes have great implications on people dependent on fish for food and income, and thus economics of their society as a whole. This chapter investigates how fisheries in the open ocean may be affected by climate change.

6.4.2 Main Findings, Discussion and Conclusions

Impact of climate change on global marine fisheries

Marine fisheries productivity is *likely* to be affected by the alteration of ocean conditions including water temperature, ocean currents and coastal upwelling, as a result of climate change (for example: Bakun, 1990; IPCC, 2007; Diaz & Rosenberg, 2008). Such changes in ocean conditions affect primary productivity, species distribution, community and food web structure that have direct and indirect impacts on distribution and productivity of marine organisms. For the open ocean, the within-year and inter-annual variability are controlled by ocean circulation, which is affected by the change in global climate. (See Chapter 4.1 for more context) For example, the frequency and intensity of the El-Niño-Southern Oscillation (ENSO) - which is a naturally occurring event that leads to change in the ecosystems, rainfall and weather patterns in the Pacific and other parts of the world - are also modified by global warming



Reef fish papahnaumokukea marine national monument

(Collins et al. 2010). However, the direction of change and the impact on the frequency of ENSO events under climate change is still uncertain. For example, in the Pacific, Lehodey et al. (2010) project a largely eastward shift (rather than poleward) for bigeye tuna under climate change: with an east-west gradient in temperature in the equatorial region that is apparently still stronger than the north-south gradient.

Another example is the Meridional Overturning Circulation (MOC), which is sensitive to the patterns of atmospheric forcing. A recent study suggested that Atlantic MOC is more sensitive to the changes in freshwater input due to global warming than that proposed in the fourth Intergovernmental Panel on Climate Change (IPCC) Assessment Report (AR4 – this is the previous IPCC Report; Dijkstra 2014). The influence of climate change on ocean circulation patterns may lead to change in species migration pattern, organism dispersal patterns and species interactions (Doney et al. 2012) and eventually the productivity of fisheries.

Empirical and theoretical studies show that marine fish and invertebrates tend to shift their distributions according to the changing ocean climate, generally towards higher latitude and deeper water (Cheung et al. 2011). There are already numerous studies showing that the change in distribution and catch potential coincided with increasing sea temperature, for example, the large increase in the catch of horse mackerel (*Trachurus trachurus*) in the North Sea (Reid et al. 2001). Other examples include the northward shift of Atlantic cod (*Gadus morhua*) in North Atlantic and Barents Seas (Rose 2005, Brander et al. 2006), and the northward shift of landings of four species (lobster (*Homarus americanus*), yellowtail flounder (*Limanda ferruginea*), summer flounder (*Paralichthys dentatus*) and red hake (*Urophycis chuss*)) in the northeastern United States (Pinsky and Fogarty 2012).

Thus, there is some confidence in predictions that a shift in species distribution and reduction in maximum body size of fish will cause the change in maximum catch potential in various countries (Cheung et al. 2010, 2012). Large scale re-distribution of global catch potential may result from climate change, with an average 30 – 70 per cent increase in high-latitude regions and a decrease of up to 40 per cent in the tropics (Cheung et al. 2010). The magnitude, variability and overall direction of change in total catch will be different across different parts of the ocean based on the location of the fishing grounds, and targeted species.

It is predicted that climate change will not only change the magnitude of landings, but also their composition. This may lead to the redistribution of fishing efforts across different fisheries, targeted species and fish locations. As such, all these changes would then impact on the economics of fisheries of the fishing nations, global food security, energy supply and food prices (Sumaila et al. 2011).

Projection of catch potential in the 2030s and 2050s

Using the methods described at the end of this chapter, the projected change in the catch potential in the open ocean for 2030 and 2050 were derived. Results are shown in Figures 6.15 and 6.16.

Figure 6.15. Change in projected catch potential (%) under climate change scenario (SRESA2) in the 2030s.

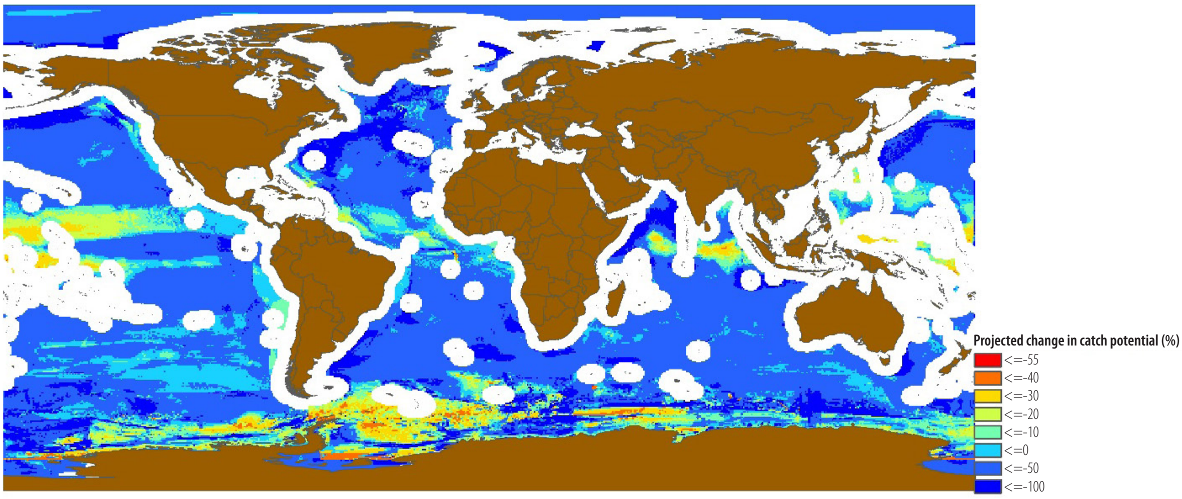
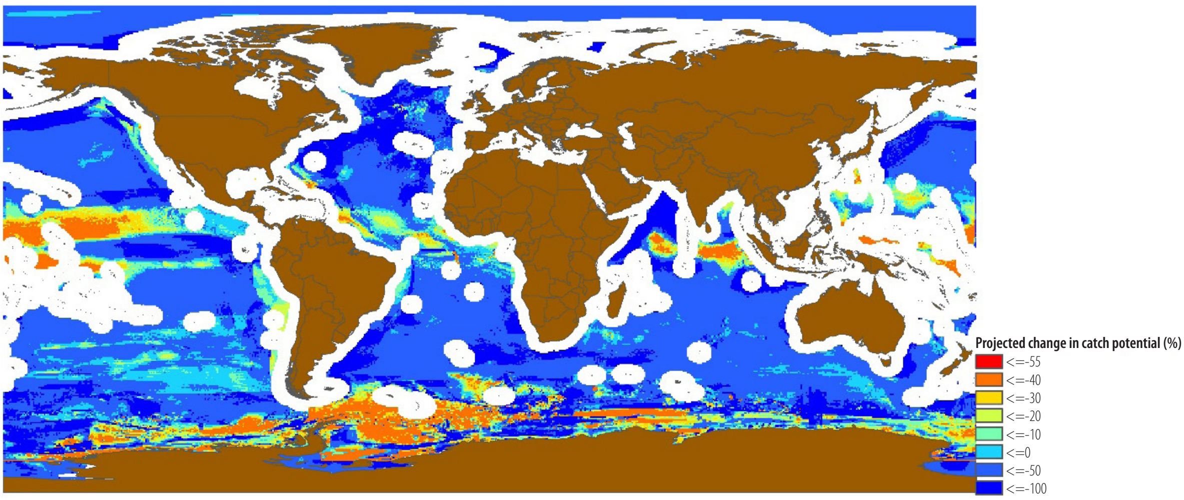


Figure 6.16. Change in projected catch potential (%) under climate change scenario (SRESA2) in the 2050s.



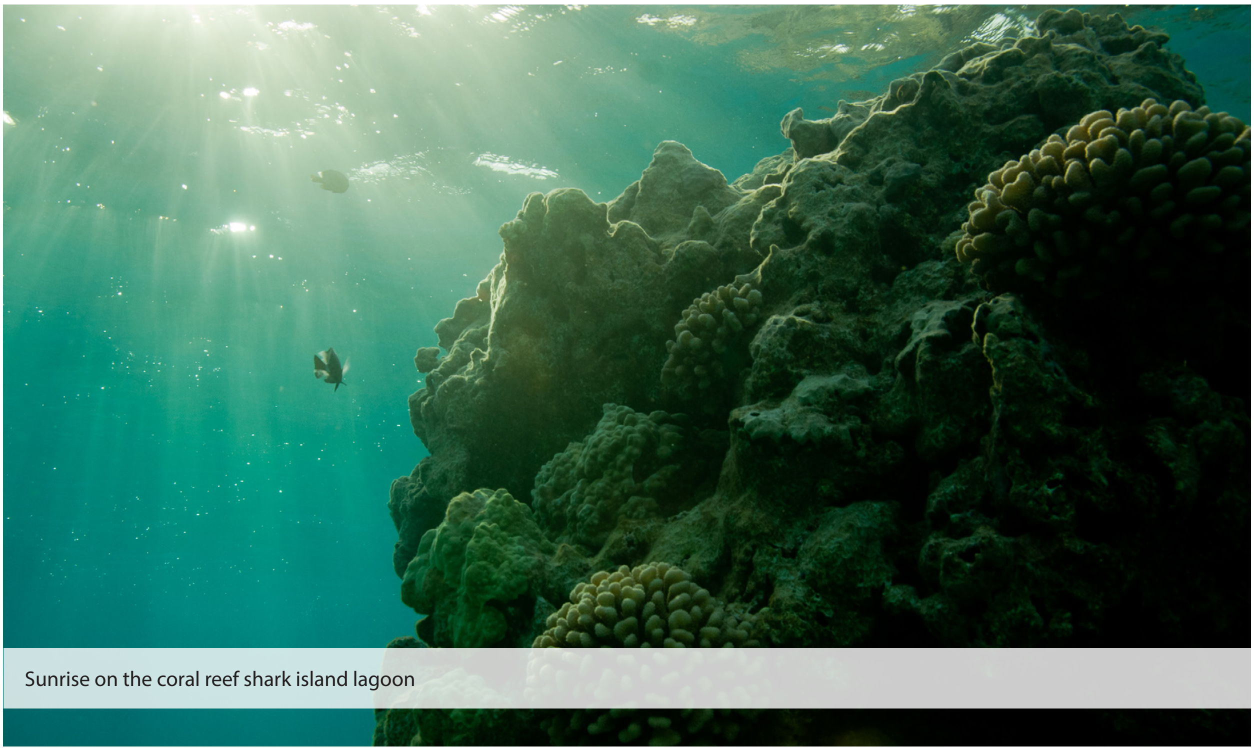
Results suggest that climate change may have a large impact on the distribution of maximum catch potential – a proxy for potential fisheries productivity – by the 2030s and the 2050s. Such a redistribution of catch potential is driven by projected shifts in species' distribution ranges and by the change in total primary production within the species' exploited ranges (Sarmiento et al. 2004; Cheung et al. 2008a).

The global catch potential decreases by 20 per cent from the current status in the 2030s under the high emission scenario, for example: SRES A2 (Nakicenovic and Swart 2000) as described in the methods section at the end of this Chapter. The longer term effect is even stronger, with a predicted global catch potential drop by 34 per cent from the current status in the 2050s. The catch potential decreases most in the tropics, particularly in the central Pacific region, in both the 2030s and the 2050s (Figure 6.15 and 6.16), where increased stratification (Polovina et al. 2011) should reduce primary and secondary production. As well, equatorial species shifting to higher latitudes are not likely to be replaced. In contrast replacement of species adapted to temperature changes in subtropical, temperate and polar regions is *likely*. The results of modeling also predict massive reduction of catch potential around Antarctica, *likely* due to the life cycle of krill (*Euphausia superba*) being strongly linked to Antarctic shelf ice, which is predicted to melt away (Marschall 1988; Nicol 2006). In addition, the planktivorous competitors of krill (salps), which are experiencing an increase in the region (Atkinson et al. 2004), are not exploited by fisheries. Consequently, the fishery potential of the Antarctic region is *likely* to significantly decline. The situation in the Arctic is predicted to be different: sea ice associated endemic species of fish are expected to be replaced by cold temperate species of economic value to the fisheries industry.

The projected change in maximum catch potential in the open ocean may have large implications for global food supply and food security issues. If the decrease in catch potential in the tropical regions directly translates to actual catch decreases, climate change may have a negative impact on food security in many countries. Such communities may already have high socioeconomic vulnerability to climate change in fisheries (Allison et al. 2009). The shift of catch potential may also render fishing activities more costly as fishing boats may have to move to other fishing grounds which maybe further offshore. Large industrial fishing fleets and distant water fleets, may have to travel further to fishing grounds at higher latitudinal regions in order to locate the marine fish and invertebrates that are predicted to migrate under climate change. Hence, travel distance for fleets may increase, which is *likely* to lead to an increase in fishing cost. In addition, as most marine fisheries resources in the world are currently fully exploited, over-exploited or collapsed and the global marine catch appears to reach or has exceeded its biological limits (Pauly et al. 2002; FAO 2008), it is expected that climate-induced changes in catch potential will strongly affect global fisheries production and food supply.

Conclusions

In the models applied for this work, the projection of global catch potential under climate change predicts that open ocean fisheries are vulnerable to impacts. This in turn will have consequences on future food supply from the open ocean and in turn, the livelihood of people and countries depending on marine fisheries. Estimates suggest that the high-range greenhouse gas emission (SRES A2) could result in an overall reduction, and a redistribution of world-wide catch potential in the open ocean for example: with an average of 30–70 per cent increase in high-latitude regions and a drop of up to 40 per cent in the tropics. This redistribution would impact industrial fleets operating in the high seas and hence the economics and food security of the countries fishing in the open ocean.



Sunrise on the coral reef shark island lagoon

6.4.3 Notes on Methods

Models and scenario for projection

Distribution shift of exploited marine species was investigated using a dynamic bioclimate envelope model (Cheung et al. 2008b, 2009). Cheung et al. (2008a) has developed an empirical model that predicts maximum catch potential based on primary production and distribution range of 1,066 species of exploited fishes and invertebrates. Our analysis included 1066 species of exploited marine fishes and invertebrates, representing a wide range of taxonomic groups, ranging from krill, shrimps, anchovy and cod to tuna and sharks. These are the species that for which there is distribution information. Overall, they contributed 70 per cent of the total reported global fisheries landings from 2000 to 2010 (*Sea Around Us* database: http://www.seaaroundus.org). The remaining 30 per cent of the global landings were reported in the original FAO fisheries statistics as taxonomically aggregated groups such as groupers (Epinephelidae) and snappers (Lutjanidae). Given that the species composition of these aggregated groups is unknown, they were not included in the analysis. An updated version of this model was applied to evaluate how changes in primary productivity and species distributions under climate change would potentially affect the productivity of fisheries in the open ocean. Only one climate model was used here because of limited resource.

In our analysis, SRES A2 scenario (Nakicenovic and Swart 2000), which assumes carbon dioxide concentration at 720ppm by year 2060, representing high-range of greenhouse gas (GHG) emissions was considered. The A2 scenario was selected because it is consistent with the current level of emissions (Rahmstorf et al. 2007) and is conservative regarding the level of global economic growth (Van Vuuren and O'Neil 2006). The A2 scenario describes a very heterogeneous world with regionally orientated economic development, high population growth, and slow technological changes (IPCC 2000, 2007). Under this scenario, the average temperature is projected to increase by 3.4°C by the 2100s relative to the current temperature. The A2 scenario is between the Representative Concentration Pathway (RCP) 6.0 and 8.5 new scenarios in the IPCC 5th Assessment Report (IPCC, 2013).

The climate projections were extracted from the outputs of Earth System Model (ESM2.1), which is a comprehensive ice-land-ocean-atmosphere coupled general circulation model including both physical climate and ocean biogeochemical dynamics, generated by the Geophysical Fluid Dynamics Laboratory (GFDL) of the United States National Oceanic and Atmospheric Administration (NOAA; Dunne et al. 2010). Ocean current, bottom temperature, sea surface temperature, sea ice extent, sea surface oxygen concentration, bottom oxygen concentration, salinity and primary productivity data were extracted from the GFDL ESM2.1. The outputs from the coupled model has variable resolution with grid 1° cells at latitudes higher than 30°N and 30°S, and a higher resolution towards the equator. To match with the resolution of species distribution maps in the *Sea Around Us*[36] database, the nearest neighbour method was used to interpolate the physical variables from the ESM2.1 to the resolution of 30′ in latitude and longitude. This interpolation method allows us to avoid making complicated assumptions about the relationship between the coarser-resolution model outputs and their downscaled values.

Only one scenario and one climate model were included because of resource limitation. This may lead to uncertainties in the results, however, the results are still valid as the data were based on the published results from a global climate change study (Cheung et al. 2010). More than one climate change scenario and multi-model ensemble should be adopted in the future study as well as using the most recent IPCC projections to reduce these uncertainties. Also, caution is needed regarding the projected migration of fish and invertebrate species, especially from the tropical regions, as it is difficult to assess which group of species – if any – will be replacing those that have migrated out of the tropical areas.

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36 www.seaaroundus.org

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