MANAGING SHIFTING FISHERIES RESOURCES: THE IMPLICATION OF CLIMATE CHANGE AND OVER-EXPLOITATION OF MOVING FISH STOCKS

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Abstract

The unprecedented rate of climate change and over-exploitation of resources has had a significant impact on ecosystems around the globe. In particular, the oceanic realm has encountered multiple changes to ecosystem conditions, food web dynamics and habitat constructs. Many marine species have been driven to shift their geographical range in reaction to reaching their physiological limits causing severe metabolic stress. This includes key fishery targets, such as pelagic and carnivorous fish, that supply many nations with their primary or secondary protein source. The shift also spurs an array of political and economic consequences due to the need for fisheries to follow or target different fish stocks that are no longer in their exclusive economic zone or legal fishing waters. For this reason, and many other logistical and financial reasons, management strategies have struggled to maintain and sustain fish stocks around the globe. This paper will look at a Northeast Atlantic mackerel case study, compare and analyse the implications of shifting fish stocks, and illustrate difficulties related to managing the fisheries which target these stocks. Furthermore, we highlight the need for a combination of global strategies, and smaller-scale ecosystem approaches in fisheries management to be able to sufficiently sustain fisheries and thus future food security, during a time of climatic change.

Keywords: Climate change, over-exploitation, fisheries management, Northeast Atlantic mackerel

INTRODUCTION

Since industrialisation, the rate of anthropogenic fossil fuel combustion has spurred the rapid increase of climate change around the globe. The combination of climate change and over- exploitation of resources by humans, for centuries, has had a significant impact on both terrestrial and marine ecosystems (Schei and Davor, 2011). This is particularly notable in the oceanic realm due to the important role this global-scale circulation plays in storing heat, water and carbon dioxide, and distributing these around the world (McCartney, 1996). Therefore, the recent rise in global temperatures has altered the patterns and intensities of oceanic circulation, and in consequence, ecosystem conditions, food web dynamics and habitat constructs have changed worldwide (Cheung et al., 2013). Additionally, reduced vertical mixing in the water column across lower latitudes (Brander, 2007), the introduction of competitors and pathogens, and the loss of primary producers and habitat structures has altered the growth, reproduction and distribution of many marine populations (Schei and Davor, 2011). As a result, climate-driven impacts have caused a shift in species dominance in many temperate and tropical waters around the world, leading to an array of impacts in ecosystem state, biodiversity, distribution, demography and structure key fish stocks, and thus fishery potential (Perry et al., *2005*; Wernberg et al., 2013).

In consequence, global fisheries have been under pressure to meet human demand while adapting to climatic and ecological changes. More than one billion people in the world eat fish every day as one of their primary protein sources, with the Food and Agricultural Organization (FAO) stating that in 2016, the consumption of fish increased above 20 kg per capita (FAO, 2016). The implication of anthropogenic impacts and the shift in fish stocks has highlighted the importance of fishery management practices to sustain food security in our future. For the sustainability, resilience and adaptability of ecosystems, management of fishing activity is essential (Brander, 2007), in conjunction with climate change mitigation strategies.

Trends in Species Movements

Many species are reaching their physiological limits, causing metabolic stress and a consequential change in regional distribution. The movement of fish stocks poleward has been noted across a wide array of case studies, and is projected to continue alongside the increase in average ocean temperatures (Fernandes et al., 2013). The tropicalisation of ecosystems is evident in many temperate marine waters, and due to the limited dispersal capabilities and suitable habitat for existing species there could be a result of widespread extinctions of endemic marine life (Perry et al., 2005). The range of pelagic species is noted to be higher than bottom- dwelling species due to their adaptive capability and ability to move further distances in a shorter amount of time (Cheung et al., 2009). This is important as approximately 70% of benthic primary production is consumed by herbivores, thus the altered range of pelagic fish may cause a community phase shift where dominant habitat-forming organisms are eliminated or replaced (Verges et al., 2014). As well as geographical shifts, change in depth is expected due to the variation of ecological and physiological interactions; however, this is restricted by the spatial domain (Fernandes et al., 2013).

Furthermore, as noted by Schei and Davor (2011), climate change is not the only driver of changes in fish stocks with exploited fish species exhibiting higher temporal variability than unexploited species. The high rate of fish exploitation and the consequential impact on the complex trophic food web is evident by the reduction in biodiversity and changes in trophic interactions (Pauly et al., 2005). Exploited trophic levels have decreased significantly due to the over exploitation of small pelagic fish, predatory fish and sharks, reducing the average trophic level from 3.37 in the 1950s to 3.29 recorded in the past decade (Pauly et al., 2005). This is further recognised in Figure 1 by the decrease of standard length and size of fish and invertebrate species, which was found to be strongly related with a decline in the average trophic level (Pauly et al., 2005).

Political Implications

The social organization of humans and the geological expansion and change of ecological systems have interlinked political boundaries, causing a globalized structure of fisheries, operation processes, world trade, scientific advancements and governance (Beddington et al., 2007). According to Costello et al. (2015), across 4,713 fisheries worldwide, the average fishery is overfished and classified as ‘poor health’ (Figure 2), and the projected outcome is further divergence and continued collapse of additional fisheries. Current governance frameworks designed by local and international agencies interact at both local, regional and global scales in a continuous but asynchronous manner, depending upon the development of the countries. This has made it difficult to apply global legislation or management system, whilst there remain uneven levels of participation and a portion of uncertainty in future shifts of fishery stocks.

The 1982 United Nations Convention on the Law of the Sea (UNCLOS) allows coastal states to establish exclusive economic zones (EEZs), where each coastal state has the right to manage fisheries resources within their EEZ (Munro, 2013). The 1995 Fish Stocks Agreement (UNFSA) facilitates the creation of regional fishery management organisations (RFMOs) to manage transboundary fish stocks (which are found within more than one EEZ), straddling stocks (which are found within an EEZ and the adjacent high seas), and discrete high sea stocks (Miller et al., 2013). Overall, these transboundary and straddling stocks account for approximately 20% of the marine catch, including several of the most valuable commercial species, such as tuna (Burns, 2008).

Climate change threatens transboundary and straddling stocks in particular. Fish stocks will shift without consideration of geopolitical boundaries or pre-existing agreements. In contended waters, such as the South China Sea, the movement of valuable fish stocks will likely intensify conflicts concerning EEZs. Climate change may also destabilise pre-existing agreements, as one coastal state may choose to increase their bargaining power (Miller et al., 2013). Shifts of fish stocks into the EEZ of a new coastal state can also cause problems. Under UNCLOS, coastal states are encouraged to negotiate with other relevant coastal states to develop cooperative regulations over a fishery; however, are not required to reach an agreement (Munro, 2013). Existing members of an RFMO can decide whether or not newcomers can enter the fishery, but if the newcomers disagree with the conditions set by the existing members, newcomers have the right to disregard the RFMO regulations and establish their unilateral regulations within their EEZ (Serdy, 2011; Orebech, 2013).

Socioeconomic Implications

Previous studies and models project the change of distribution of primary and secondary species will decrease the average maximum catch potential of fish stocks in the tropics and increase catch in the high latitudes (Link et al., 2010; Fernandes et al., 2013). This can be seen as advantageous for some nations in the higher latitudes, including Northern Europe and New Zealand, whose fishing grounds remain cold, nutrient-abundant, and have seen increased supply in fish stocks of formerly warm-water species (Harte, 2017). The current and future change in species distribution impacts the value of commercial fisheries (McKie, 2017; Brander, 2007), thus having serious economic and political impacts for vulnerable nations, in particular, those located in lower latitudes, otherwise known as the Global South.

Globally, 800 million people are subjected to food shortages and 2 billion people suffer nutrient deficiencies (Harte, 2017). Fish and seafood remain a crucial source of protein for more than 2.5 billion people. The small-scale and artisanal fishing industry is critical for stable food security in states across the Global South. It provides economic growth across developing nations, which in turn impacts the livelihoods of more than one billion people (Harte, 2017).

The artisanal fishing industry extends into coastal waters using small fishing boats, and generally does not have the investment or equipment to follow shifting fish stocks (Ocean Health Index, 2017). Furthermore, many of these nations do not have resource availability and are often reliant on fisheries for food production and national income (Harte, 2017). Tropical and equatorial countries throughout the Global South will be most heavily impacted by shifting fish stocks.

Bangladesh, Small Island Developing States, Peru and Ecuador have already been impacted by these ecological regime shifts (Brander, 2007; The Conversation, 2017). Historically, global fisheries have responded to shifting spatial regimes across fish stocks; however, there are now unprecedented levels of climate uncertainty, spatial dispersal across fish species and acceleration in human population growth, which further exacerbates existing pressures (Brander, 2007).

Case Study: The Northeast Atlantic Mackerel Crisis

The sea surface temperature in the North Atlantic has been experiencing a warming trend over recent decades due to climate change (Stenevik and Sundby, 2007) influenced by both rising temperatures and zooplankton availability. In consequence, the Northeast Atlantic mackerel (*Scomber scombrus*) has migrated further north and west (ICES, 2009) (Figure 3). Mackerel stocks were previously exploited by the European Union (EU) and Norway as a valuable commercial fishery, however in recent years they have entered the EEZs of Iceland and the Faroe Islands. Icelandic catch increased from 1700 tonnes in 2006 to 120 000 tonnes in 2009-10 (Astthorsson et al., 2012). The redistribution of this species also had ecological impacts in Iceland, with an estimated 3 million tonnes of food being consumed by the mackerel each year, leading to an increase in mackerel biomass by 43-55% and competition to the existing marine species (Hough et al., 2016).

The international agreements that came into play during this crisis were UNCLOS, UNFSA, and the 1980 North East Atlantic Fisheries Convention (NEAFC) (Orebech, 2013). In 2010, a bilateral agreement was reached between the EU and Norway, where their combined quotas amounted to more than 90% of the total allowable catch (TAC) (Orebech, 2013). Iceland and the Faroe Islands ignored the agreement and established their quotas. The 2010 harvest ended up being 40% above biological recommendations (ICES, 2010). The EU, Norway and the Faroe Islands eventually signed a trilateral agreement in 2014 that included relative allocations of the TAC, while Iceland continued to set its own quotas (Nottestad et al., 2016). The lack of multilateralism and inability to resolve the political dispute resulted in mackerel being fished beyond sustainable yield.

Solutions

The global phenomenon of shifting fishery resources presents a major challenge for global fisheries management. Collaborative global action and a concerted move towards cooperative management practices, including exploration of alternative livelihoods, will need to be taken to prevent vulnerable nations from overfishing remaining fish stocks (Brander, 2007; Harte, 2017). Measures must be implemented to prevent stock collapse across equatorial waters, mitigate ecosystem damage, and manage food shortages and economic failure across vulnerable nations (Harte, 2017). For managing shifting fisheries resources, it is necessary to identify and understand the drivers and constraints responsible for the shift. The management of the fisheries is mainly dependent on the characteristics of the fisheries system which includes production, resources and environmental issues, fishing capacity and sectoral diversity and contribution to food security. The main drivers and constraints governing these characteristics are demography, economic development, governance, fishing capacity, technological progress, and most importantly climate change (Kraak et al., 2012).

International Solutions

Effective governance of internationally shared fisheries with shifting resources will require improved integration of scientific research and mechanisms to encourage cooperation, in particular, contingencies in policy-making to deal with the unpredictable impacts of climate change (Miller et al., 2013). Coordination of scientific research, to set the TAC and allocate quotas among participating coastal states, should be the responsibility of RFMOs. However, as of 2007, only one of the 17 UN-recognised RFMOs took explicit action on climate change, and only eight RFMOs addressed climate change in at least one annual meeting (Axelrod, 2011). As more fish stocks are displaced from their original boundaries, it also becomes increasingly important to incorporate newcomers into the decision-making processes of an RFMO. There have been two suggested solutions for this. The first is to develop transferrable membership quotas, where newcomers may buy quotas from existing members of an RFMO (Serdy, 2011). The second is to allocate quotas based only on the geographical distribution of adult biomass, eggs and larvae (Orebech, 2013). It should be noted that both solutions may favour developed regions, as developing nations may find it difficult to buy membership quotas, and would have to deal with the loss of both terrestrial and marine food resources from climate change.

Local Solutions

The shift in fishery resources means that a combination of both world-wide and small-scale highly controlled management approaches are necessary. Traditionally, fishery management has focussed primarily on fish biomass and mortality at a large scale, but due to the change in fish stocks globally, the difference in economic capabilities and independent national priorities, finer-scale ecosystem approaches in conjunction with global fishery regulations, may provide the most sustainable fishing practices (Kraak et al., 2012; Costello et al., 2015). This will encompass mixed-fisheries and multispecies interactions. In particular, education and further studies are crucial in the development of sustainable fishing practices in both developed and developing nations (Kraak et al., 2012). For example, the Green Paper of the European Commission proposes a top-down regulation change and the strengthening of stakeholder participation to help develop fisheries management plans (Daw and Gray, 2005). Evidence highlights an increase in successfully reached objectives when the fishers are a part of the decision-making process (Kraak et al., 2012). Further, the increase in fish consumption in many developing countries, puts additional pressure onto small commercial and recreational fishing practices, leading to overfishing and the use of ecologically harmful fishing practises. Therefore, the enforcement of fishing regulations, including locational and temporal fishing limits, restrictions on type and size of equipment, and the size and engine capacity of fishing vessels, are essential to be carried out by recreational and commercial fisheries to ensure the balance between optimizing the yield of fishing and marine conservation efforts.

Studies conducted on the present state of the fisheries has highlighted the need to recognise and assign total legal catch, estimation of the illegal catch (Figure 4) and the amount of fish dumped as waste, to help identify management practices that can be employed (Agnew et al., 2009). The structural and functional diversity of the fishery sector needs to be studied and analysed in order to understand the trends and predict future changes which will aid in the management and conservation. This will include new technological inventions and investments, local and global business models, implementation of data-supported legislation or jurisdiction, and a stronger understanding of the production chain, related processes and distribution of fish stocks.

CONCLUSION

The unprecedented nature of climate change, increase in human populations and the demand for food security, highlights the importance of creating sustainable fisheries for future generations. The lack of management enforcement, the variation of national obligation, lack of knowledge and commitment by global parties, economic differences and political competition, has meant that fishery management has struggled to reach global objectives. The future of fishery management needs to employ a variety of sustainable ecosystem-based small scale initiatives and larger-scale global policies to match the detrimental effect of moving fish stocks and re-establish fish numbers. This will help to address the serious issues both developed and developing countries are facing in the uncertain future of climate change.

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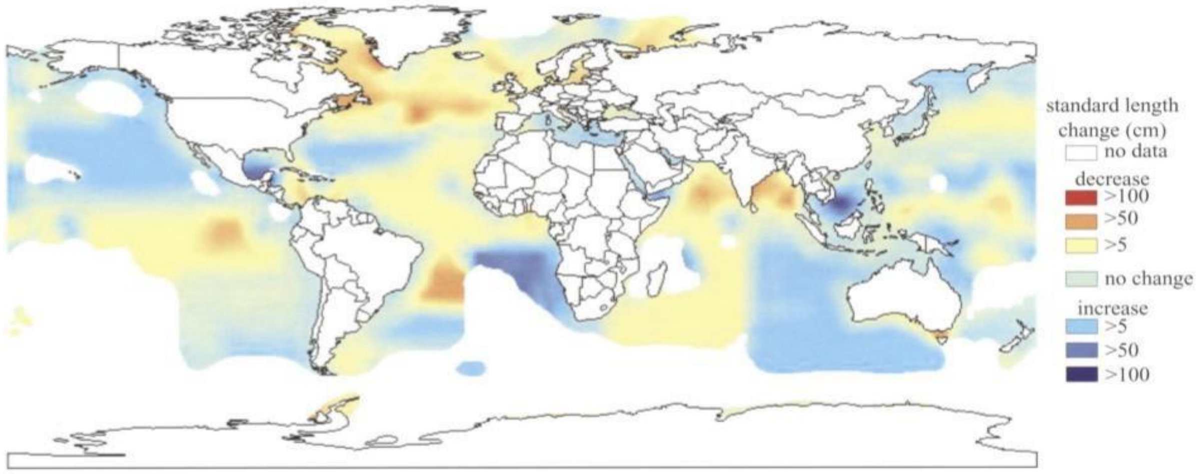

Figure 1. Difference between the mean maximum length of fish and invertebrate species in fisheries landing between the 1950s and the 1990s (Pauly et al., 2005).

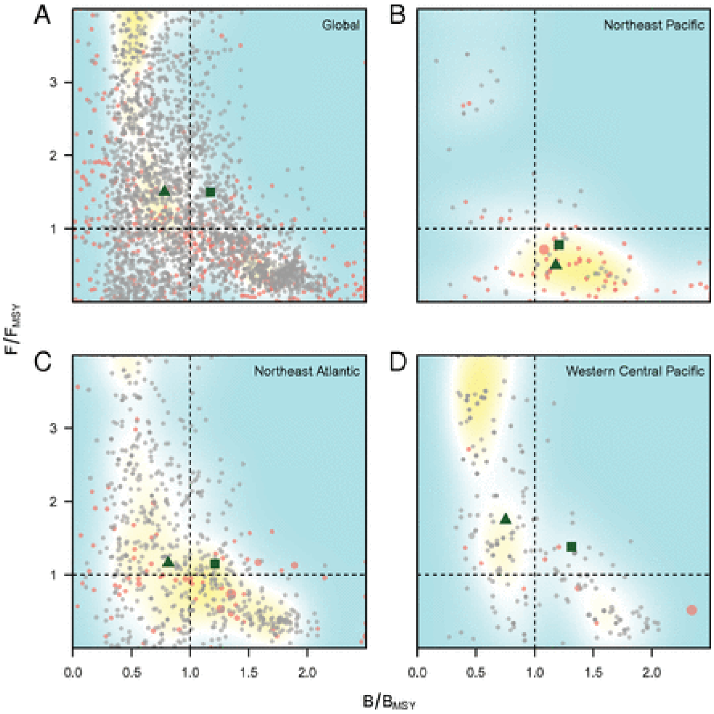

Figure 2. (left) 'Kobe' plots indicating the current fishery status in the (A) Global, (B) Northeast Pacific, (C) Northeast Atlantic, and (D) Western Central Pacific, with RAM data (red dots), unassessed fisheries (black dots), median (green dots) and catch-weighted mean (green squares) indicated accordingly (Costello et al., 2015).

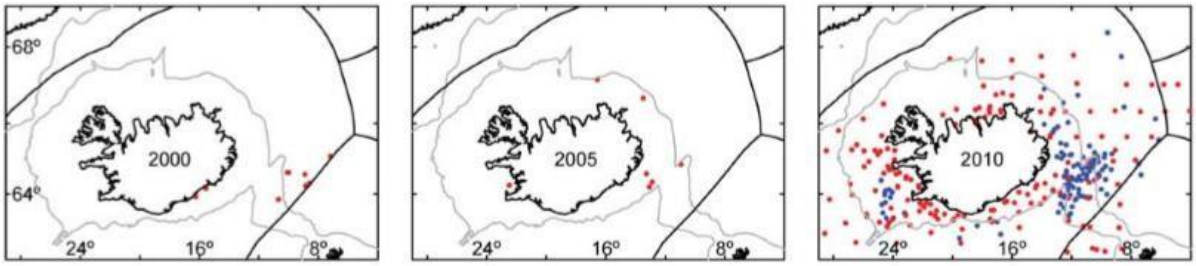

Figure 3. Locations of mackerel catches from scientific surveys by the Marine Research Institute (red) and
of mackerel samples taken by the Icelandic pelagic fishing fleet (blue), 2000–2010. (Astthorsson et al., 2012).

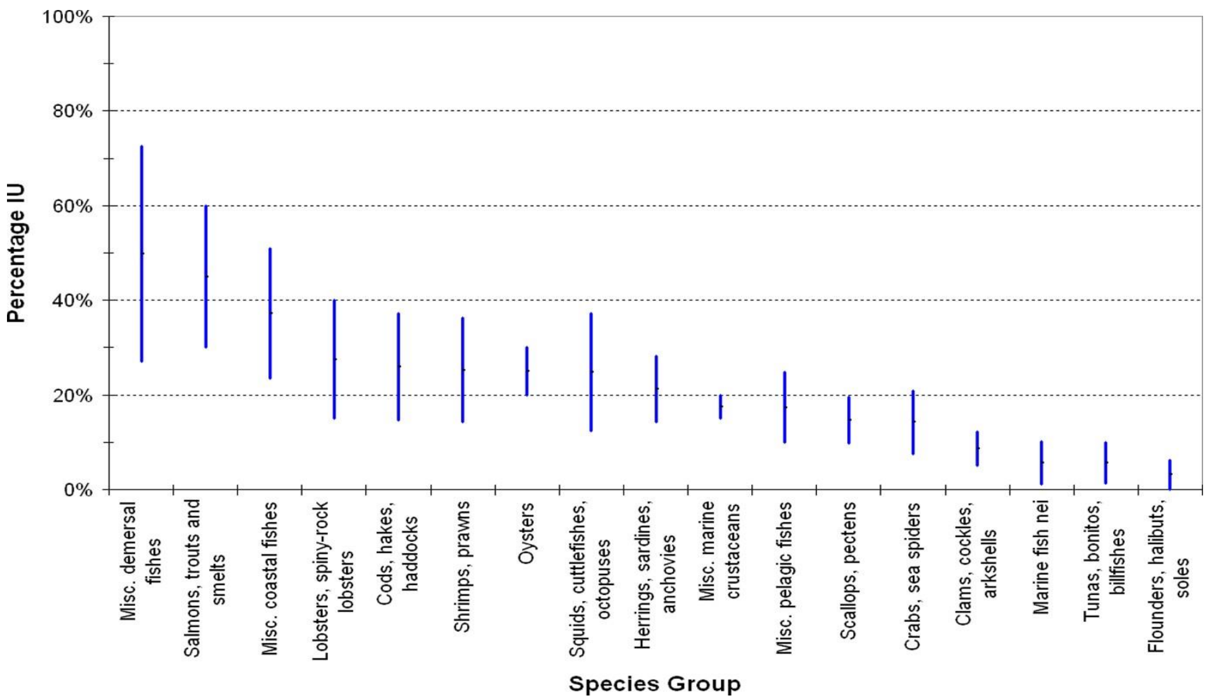

Figure 4. Illegal and unreported catch, expressed as a percentage of global reported catch, by species group from 2000 to 2003 (Agnew et al., 2009).