IMPLICATIONS OF CLIMATE CHANGE ON THE FISHERIES SECTOR AND THE METHOD USED TO ASSESS THE VULNERABILITIES OF CLIMATE CHANGE

Lubna Alam and Nur Nabila Huda binti Sazali
Research Centre for Sustainability Science and Governance, Institute for Environment and Development (LESTARI),
Universiti Kebangsaan Malaysia, Bangi, Selangor.
Contact: lubna762120@gmail.com

ABSTRACT: *This paper reviews the implications of climate change on fisheries sector. The fish is valuable for many reasons, economy, environment, and social. The fisheries sector is important for our nation, fish is one of the protein's sources that Malaysian's people consume the most. However, the oceans of the world are changing with an increase in temperature and acidity, and changes in salinity in all ocean basins. Extinction or changes of species occurred may give an impact on our economy indirectly. They are expected to occur when the distribution's ability is restricted or suitable habitat is unavailable. Climate change not just affecting the environment, it also affects the social and economy indirectly. The literature indicates that climate change poses risks to the fisheries sector in many ways. These studies have been carrying out in a few locations and also used observations from past to infer future changes, and havnure used numerical simulation models with climate change scenarios to predict the consequences for the future. The paper will discuss climate change projection and the impact of climate change from one period to another. The paper has also provided a few methods from previous research on how to assess the vulnerabilities of climate change. They provide a framework for a systematic assessment of the implications of climate change on the fisheries sector, but somehow showing that there are more research need to be done to help us understand and prepare us for the next consequences.*

INTRODUCTION

The fisheries sector is important for our nation, fish is one of the protein's sources that Malaysian's people consume the most. It is also an important source of jobs in the region. There are serious apprehensions about overfishing as the main reason for the decreasing fishing stock. The extinction or change of species due to climate change may directly give a big impact on our fisheries sector due to current reduced of fish stock, it also will affect the income of fisherman as the catch is reduced and indirectly will affect the social when people will lose interest in becoming a fisherman.

Climate change is likely to impact on the world's oceans by increasing stratification, causing reductions in the availability of nutrients to the photic zone, affecting the strength of major ocean currents, causing changes in upwelling, mixing and transport of nutrients, reducing dissolved oxygen levels and causing sea levels to rise [1]. In turn, these changes are predicted to reduce overall primary productivity and change the biomass and composition of lower trophic levels, leading to changes in the structure of food webs that support oceanic fisheries [2]. Many of the species and infrastructure are likely to be heavily affected by climate change [1].

The studies on the assessment of climate change vulnerability on the fisheries sector has been done at the global level but the assessment at the local on the small scale fishers of the tropical region is still trifling. There are few methods used to assess the vulnerabilities of climate change toward fisheries sector in previous research that been discuss in this paper review.

Importance of Fisheries Sector

Realizing the importance of the sustainable level of fish production in Malaysia, the ministries introduced a zoning system in coastal waters which prohibits fishing vessels from intruding on nursery and breeding grounds to prevent lessening of fish stock. Studies conducted in Sabah on the coastal resources in the 1970s have shown that up to 65% of all commercial marine fish species spend part of their life in mangroves, estuaries and coral reefs. [3]

According to a report by the World Commission on Dams, 20% of freshwater fish have gone extinct, globally. Extinction is expected to occur when the distribution ability is restricted or suitable northward habitat is unavailable, it may have an impact on our economy and social indirectly. The biological diversity will be threatened by the fast climate change, which may alter the composition and geographical distribution of ecosystems. Species that are unable to adapt quickly could become extinct, representing an eternal loss. [4, p. 259]

The expected decreases in fish production due to climate change are very high and worries that it may contribute a negative impact on food security. As an example we can take the leatherback turtle (Dermochelys coriacea) as a case study in Malaysia, Leatherback turtle is the largest species of sea turtle, "In the 1960s, there were records of up to 10,000 turtles coming ashore annually. However, over the last three decades, there had been a steady decline in the number of turtles coming in to lay their eggs. One of the reasons for the decline was that nearby villagers collect and sell the eggs.

Since 1961, there have been efforts by the Fisheries Department, assisted by universities and conservation groups, to buy and hatch eggs in artificial nurseries and then release the hatchlings to the sea. Even when the turtles come back to the beaches, it was found that the eggs have very low hatching rates. Studies have shown that most turtles hatched artificially were female because of the higher temperature in which they were incubated and it is one of the effects of climate change. The fall in the number of male turtles has resulted in difficulty for the female turtles to find male turtles to mate. By 2001, the number of turtles coming back was only 21 and none of the eggs hatched. In 2004, only three turtles came ashore and there was no record of the eggs hatching." [3].

Observation and Projection of Climate Impact on Fisheries

Climate changes have been observed approximately every 120 thousand years, developing with a larger or smaller extension at least five times in the last 500 thousand years [4]. Historical records and near real-time ocean observing and analysis systems indicate that the oceans of the world are changing with an increase in temperature and acidity, and changes in salinity in all ocean basins [2]. Changes to ocean processes due to climate variability are now begun to modify the food webs that support oceanic fisheries, resulting in more permanent shifts in the distributions of fish species [2].

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The metabolism of fish is influenced by a variety of water quality parameters including temperature, salinity, and pH. Most freshwater and marine fish are unable to regulate their body temperature. The increase in metabolic rates has important implications for energy use, growth efficiency, and upper lethal limits, an example is Phytoplankton has increased in the cooler regions and decreased in warmer regions, the phytoplankton decreased effect other parts of the ecosystem through the food web [5, p. 194]. The higher temperature of the water will lower the level of dissolved oxygen for larvae, and research indicates that less dissolved oxygen will affect the fish from mortality to altered trophic interactions thus, will lead to hypoxia and unstable oxygen concentration will harm reproduction, immune response, and growth [6, 2009]. Trends observed in the physical structure of the oceans are projected to continue during the 21st century with mid-range warming estimates in the order of 2 to 3 °C by 2100.

Increase of tropical storm activity could have a large impact on the fishing and aquaculture industries, because of many factors such as the increased of pollution run-off, direct storm damage, flooding, saltwater intrusion from storm surge and habitat loss, furthermore the fishing industries could be shattered by the damage and loss of infrastructure including boats, docks, marinas, equipment, processing plants and distribution centers.

Sea level rise is predicted to be the greatest impacts of climate change on fisheries sector, especially on the fisheries and aquaculture in areas of shallow water where the estuarine location may shift significantly. Sea level is projected to rise by approximately 18–26 cm by 2050 in south-east England, and sea surface temperatures to increase by of the order of 0.2–0.3oC per decade [7].

Higher atmospheric CO_2 concentrations will cause increasing acidification of the surface ocean. Multi-model projections based on IPCC Special Report on Emissions SRES scenarios indicate that reductions in pH of between 0.14 and 0.35 units are likely to occur [2, p 215]. The result from lower pH will decrease the saturation state of calcium carbonate and leads to decreased calcification in marine organisms [8]. Experimental studies of larval growth and survival have shown that higher levels of acidification would lead to a decrease in growth and survival.

Available methods on vulnerabilities assessment of fisheries sector relating climate change

The studies on the assessment of climate change vulnerability on the fisheries sector have been done at the global level but the assessment at the local on the small scale fishers of the tropical region is still trifling. A composite vulnerability index (0.0–1.0) has been developed on the basis of functional relationships amongst sensitivity, exposure and adaptive capacity by using 19 indicators related to inland fisheries, the vulnerability assessment approach is by using index-based wherein each component are individually constructed and combined [9]. The data obtained reflected different spatial combinations of climate exposure, sensitivity and adaptive capacity among the districts.

The study was conducted in a few different places, for each place, 19 individual indicators associated with the three main components such as sensitivity, exposure, and adaptive capacity were collected from various sources. The developed framework is projected to provide a practical analytical tool to understand the contribution of the indices of the sector to climate vulnerability at the district level for developing local adaptation strategies (Figure 1) [9, p. 280].

To study the climate variation on the temperature and rainfall pattern, the time series data for certain period on the climates variables, daily rainfall, maximum temperature and minimum temperature for all the chosen place were collected (9, p. 281). However, there is no independently derived measure of exposure, sensitivity or adaptive capacity (9, p. 286)

Table 1: Framework for construction of vulnerability index [9].

Indicator	*Weight*
Sensitivity	
S1	Total Inland Fisheries
S2	Total Fish Seed Production
S3	Prawn/Shrimp Production
S4	Total Fish Cultured Area
Exposure	
E1	Variance In Annual Rainfall
E2	Mean Minimum Air Temperature Variance
E3	Mean Maximum Air Temperature Variance
E4	Flood Prone Area
E5	Cyclone Risk
E6	Density Of Population
Adaptive Capacity	
A1	Total Main Worker
A2	Total Agricultural Labours
A3	Total Fishers
A4	Marginal Workers
A5	Non-Workers
A6	Total Industrial Worker
A7	Literacy Rate
A8	Infant Mortality Rate
A9	Per Capita Income

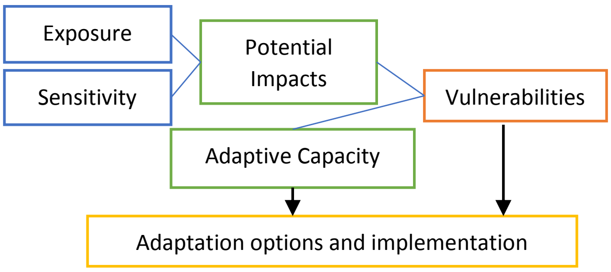
For the second method, the researcher observe regime shifts of the environment locally and globally together with biological variables. "A comprehensive conceptual model involving few aspects such as environmental, biological and anthropogenic was established for swordfish captured in offshore Chile" [10]. To project the model, the average structure of catches and temperature of Antofagasta for the years 2005, 2006 and 2007 were used as a starting point. Researcher considers a linear increase in temperature, taking into account four climate change scenarios based on the scenarios presented by IPCC" [10].

Another method is by using a selection process, "The selection considered few aspects such as current levels of harvest, economic value, and cultural and social importance. 15 species chosen for the assessment symbolize a range of marine taxonomic groups with contrasting biology and ecology, there are exploited to varying degrees by different fishery sectors. The researcher conducted a review of each species selected with a particular focus on their sensitivity to climate drivers and the ability of the fishery to adapt to change" [10].

"The researcher also assessed the vulnerability of habitats that support fisheries in the Torres Strait based on previous research, thus conclude the extent and status of estuarine, seagrass, mangrove and coral reef habitats in the Torres Strait, and known sensitivities of these habitats to climate drivers. The vulnerability of these habitats has been assessed in adjacent comparable regions using the same framework, and those results were used for this study. The researcher applied a semi-quantitative approach to assessing multiple fisheries species vulnerability based on a framework that includes the elements of exposure, sensitivity and adaptive capacity proposed by the IPCC." [10].

The framework used to assess the vulnerability of Torres Strait fisheries to climate change that integrates socio-ecological indicators for exposure, sensitivity and adaptive capacity adapted from [11].

Indicators for each species were scored consistently and directly using available literature, relevant expert assessment from a pool of 11 fisheries and biological scientists, and indirectly using local Indigenous fisher knowledge (10 fishers) stimulated through a structured interview process conducted by telephone or in person.



Based on certain criteria for each element, an index was calculated as the average score by dividing the total score by the number of indicators. The potential impact index (PI) was calculated as the product of exposure (E) and sensitivity (S) indices. However, since the scoring framework does not accommodate direction of impact, the final PI index was derived by incorporating a direction of impact (DI) value. The DI value was: negative =1, unknown or neutral =0, or positive = −1. Due to the effect of standardization, 1 was added to avoid zero values, which may imply a species has no vulnerability. Ec is the economic value score and C is the cultural value score.

CONCLUSION

"The results of this work emphasized the necessity to analyze the influence of environmental factors on fisheries from a given area and assess the capture and biodiversity predictability under a climate change framework in order to develop more effective management policies. The knowledge related to the functional relations between the fishing resources and the environment is crucial for planning future scenarios, thus facilitating the control of the plausible effects of such changes on fisheries management. The integration of calibrated models into specific applications is needed, allowing the estimation of fisheries performance in different scenarios of climate change and obtaining a first approximation to the probable economic and social implications, taking into account medium and long term scenarios considered in fisheries management" [9].

Studies have been undertaken in a very small number of locations, and it is clear that the impacts of climate change will depend on local conditions and influenced by various indicators. Climate change is likely to impact on the world's oceans by increasing stratification, causing reductions in the availability of nutrients to the photic zone, affecting the strength of major ocean currents, causing changes in upwelling, mixing and transport of nutrients, reducing dissolved oxygen levels and causing sea levels to rise [1]. In turn, these changes are predicted to reduce overall primary productivity and change the biomass and composition of lower trophic levels, leading to changes in the structure of food webs that support oceanic fisheries [2]. Many of the species and infrastructure are likely to be heavily affected by climate change [5].

The framework of the method presented provides policy-makers and stakeholders a reason for evaluating the spatial vulnerability of the inland fisheries sector to climate variability in states at a sub-national level. However, there is an urgent need to continuously improve the assessment based on major components such as exposure, sensitivity and adaptive capacity for more knowledge in vulnerability analysis in the future. Thus, future applications should include other environmental impacts in a spatial-temporal dimension to the phenomena that occur at different scales.

The key factors contributing to fisheries' high vulnerability were lack of species mobility, species near their thermal distributional limits, strong habitat associations particularly for species reliant on seagrass meadows, the strong dependence of the fishery on a single species, and inflexible or non-adaptive management [10]. Understanding these vulnerability sources provides specific targets for action that will promote strategies to manage future climate risks and maintain fisheries sustainability. By focusing, adaptations strategy on certain focus species will minimize sources of vulnerability and indirectly reduce future impacts of climate change, so that "adaptation strategy will meet community imperatives for food security and livelihoods, and be selected and implemented by stakeholders [10]

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