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Impacts of Climate Change: Can Fisheries and Aquaculture Sectors Survive the Wave?

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Abstract

Studies have shown the impact of climate change on the ocean ecosystem and the fishing and aquaculture sectors. As global warming intensifies, this will impact communities and communities as the populations of some fish species decline or increase. Research on the impacts of climate change to fisheries will facilitate the development of policies, helping communities to adapt while ensuring resilience and sustainability of the sector(s). This paper assesses the short term and long-term impacts of climate change to the ocean ecosystem, the consequences to economies and communities that rely on fishing for food security. It begins with a review of peer reviewed literature, followed by an analysis of the current policies and ends with some recommendations for governments in the sustainability and management of the ecosystem in the future. Important to note is the impact of human generated hazards and how a more holistic approach to minimizing risks to the ocean ecosystem could resolve threats of food insecurity in future.

Keywords: Climate change, Coastal communities, Food security, Aquaculture, Fisheries and Atlantic Canada

1. Introduction

Canada's marine ecosystems are undergoing significant changes related to a combination of factors such as climate change, natural variability as well as human pressures such as fishing (Chu, Mandrak, & Minns, 2005; Fisheries and Oceans Canada, n.d). Climate change affects the availability of food and oxygen to maritime species. This has significantly impacted communities that rely on the oceans for their livelihood. Seafood consumption and fishing

activities have increased worldwide putting stress on fishing stocks. A 2018 report by the United Nations Food and Agriculture Organization (FAO) on the State of Fisheries and Aquaculture shows that the overfished marine stock reached a peak high in 2015 at 33% simultaneously with a peak low of 7% (Cheung et al., 2009; Vázquez-Rowe, 2020, p. 1). World oceans are currently experiencing the short-term impacts of climate change as absorption of GHG emissions increase. Research has shown that climate change impacts will significantly change the availability of fish and fish products which will cause economic and environmental consequences for some regions and countries. Short term impacts of climate change include losses of productions and infrastructure as a result of floods, increased disease risks such as parasites and harmful algal blooms (Vázquez-Rowe, 2020, p. 3).

The Pan-Canadian Framework on Clean Growth and Climate Change recognises the impact of climate change to coastal regions and communities. Although not all marine populations respond negatively to global warming, further research can help to assess the impact that these changes may have on fish landings and ultimately on the fishing communities as they adapt to the ecological changes of climate change (Vázquez-Rowe, 2020, p. 2). The Intergovernmental Panel on Climate Change (IPCC) report on climate change and the world oceans gives evidence of the impact of climate change on economies, businesses and communities that rely on fishing for livelihoods and nutrition. Furthermore, it also includes evidence on how the changing structure of the ecosystem is affecting potential food catches (Heck, Béné, & Reyes-Gaskin, 2007; Marine Stewardship Council, 2019). Countries do acknowledge the need for adaptive measures under the Paris agreement to protect fishing grounds and fishing infrastructure at risk of increased sea levels as a result of ocean melting (Vázquez-Rowe, 2020, p. 2). Investigating vulnerability and adaptation measures will help in the prevention, preparation for and reduced impact of extreme events on the fisheries and aquaculture sectors (Cooke et al., 2018; FAO, 2018, p. 513). It is important to note that there are other numerous human-generated hazards that are threatening ocean species such as nutrient loading, costal littering, hence, the need for immediate action to minimise the impacts to ocean wildlife and food insecurity concerns (Wang, Somogyi, & Charlebois, 2019).

The paper attempts to respond to the following questions: What are the long-term impacts of threats to the ocean ecosystem to the Canadian economy, particularly Atlantic Canada and what should governments do to help mitigate risk? Some suggestions are made, and future research paths are provided for both research and sound policy.

2. Impacts of Climate Change on the Aquaculture Ecosystem

Fisheries and aquaculture play a significant role in food security, providing a source of livelihood for communities, while bringing some economic, social and nutritional benefits (Kent, 1997; Charlebois, Stern, & Buhr, 2014; FAO, 2018, p. 41). The last few decades have seen an expansion of the fishing industry and trade as fish products and consumption have broadened. As the impacts of climate change are being seen in the fishing and aquaculture industry, this is expected to come at high economic costs for many countries and economies. Global population growth is also putting pressure on fish markets, leading to higher fish prices (FAO, 2018, p. 41).

Global warming has significant impacts such as precipitation, temperature changes, climate

patterns and the melting of snow which may affect the quality, quantity and seasonality of waters leading to inevitable changes to the ecosystem (Charlebois & Labrecque, 2009; FAO, 2018, p. 4). Increases in air temperature are also expected to lead to an increase in water temperature for freshwater systems and this will create shifts in water species distributions and the loading of nutrients. While the long-term impacts of climate change to aquatic systems are not easy to measure, there certainly will be some implications for fisheries and the aquatic sector throughout the value chain. This will then alter species productivity and fish growth leading to consequences for fishing and farming yields as shifts in the distribution of fish occur (FAO, 2018, p. 10). This will impact fish farmers and communities reliant on the fish industry creating major food control measures that will ultimately impact consumers as contaminants and toxin levels in fish increase due to changes in water conditions (FAO, 2018, p. 11).

There has been a worldwide increase in greenhouse gas (GHG) emissions which is partially generated by the fishing industry leading to induced ocean warming, altering food webs in the marine environment, large scale redistribution of marine species and higher levels of psychological stress in marine biota (Vázquez-Rowe, 2020, p. 2). Furthermore, Free et.al. in their study found that maximum sustainable yields of worldwide fisheries had decreased by 4.1% between 1930 and 2010 as oceans continue to absorb human GHG emissions (Vázquez-Rowe, 2020, p. 2). In the North Atlantic, global warming is expected to continue rising and this could impact fish stocks. Climate change is expected to have either significant positive or negative impacts depending on the productivity of each geographical location (FAO, 2018, p. 97).

3. Fisheries and Seafood in Northern Atlantic

Fisheries and aquaculture contribute significantly to the food security of many communities, creates employment, supplies nutritious food and generates income leading to economic growth (FAO, 2018, p. 42). Although in most countries fisheries and aquaculture represent a small portion of the overall labour force and economies, these are crucial for coastal, riverine and inland regions which heavily rely on these sectors (FAO, 2018, p. 42). Approximately 200 million people worldwide are directly employed through the value chain from fish harvesting to distribution (FAO, p. 42). In 2016, a record 171 million tonnes total fisheries and aquaculture were produced, with an estimated US$262 billion in production (FAO, 2018, p. 42). Fish and fishery products are among the most traded foods in the world with an estimated 78% of products being exposed to international trade (FAO, p. 48). In 2017, the trade of fish and fish products was expected to reach a record US$152 billion, however, in the last few years, the industry has experienced reduced growth rates. As already indicated above, this decline is expected to impact tax revenues, foreign exchange earnings, employment, supply, income and sources of nutrition for some countries (FAO, 2018, p. 49).

According to FAO (2018), climate change is expected to affect the availability of fish and fish products, circulation of goods, production, and distribution of several fish species. As the industry faces changes to fish resources, this will put pressure on international fishing agreements as well as governance. Climate change is expected to alter aquatic food prices which will affect resources, infrastructure, the global supply, costs of goods as well as the services required in the production, processing and distribution of products (FAO, 2018, p.

50). It is projected that changes in temperature will lead to reduced availability to local markets and contribute to increased food prices by 2050. This will lead to major impacts on economies and the food security of communities that rely on the fish and aquaculture industry for nutrition and income (FAO, 2018, p. 50).

There are specific communities in North Atlantic, such as the Inuit in Canada, whose livelihoods are mostly dependent on the fisheries for food security. These are especially at risk and most vulnerable to the effects of climate change. The Northwest Atlantic areas, including the Grand Banks of Newfoundland have seen a decrease in Atlantic herring and mackerel while seeing an increase in other fish such as squids and longfin (Bene & Heck, 2005; Curtis et al., 2014; FAO, 2018, p. 88; Foley, 2019). At the same, Atlantic waters off Canada in Nova Scotia, Newfoundland and Labrador have seen an increase in valuable shellfish such as lobster, snow crab and shrimp (FAO, 2018, p. 88). Overfishing in the Northwest and Northeast Atlantic as well as warming declines in productivity have led to a collapse in cod stocks in Canada and unprecedented increases in catches of American lobster, snow crab and shrimp. Extensive fishing can cause fishing populations to become more vulnerable to short-term natural climate variability (FAO, 2018, p. 98). Furthermore, climate change may make stocks more vulnerable to fishing, reducing overall carrying capacities of stock. Climate change is also expected to impact traditional harvesting techniques in Inuit as changes to the composition and productivity of fish occur (Beard et al., 2011; FAO, 2018, p. 100). Hare et.al (2016) conducted a climate vulnerability assessment for 82 fish species in northeast of the United States of America. They found that overall climate change vulnerability; the extent to which abundance or productivity of the species could be impacted by climate change, was higher for salmon and Bay scallop. Negative effects were projected for approximately half the species assessed although some will be positively impacted due to abundance and increased productivity (FAO, 2018, p. 101; Jin & Thunberg, 2019).

Wilson et al. (2020) conducted their research on the socio-economic impacts of climate change and ocean acidification on future shellfish species in Atlantic Canadian fisheries. Seafood production in Canada is concentrated on the Atlantic Coast with over 80% of total landings and over 85% of the commercial fishing based in the region (Wilson et al., 2020, p. 2). Atlantic Canada is highly dependent on fisheries that are susceptible to climate change and ocean acidification. Rural populations with relatively smaller communities are highly dependent on employment from the fisheries and aquaculture sectors (Nasser et al., 2011; Wilson et al., 2020, p. 1). In their research, they found that New Brunswick and Nova Scotia are likely to see declines in resource accessibility due to climate change and ocean acidification while Prince Edward Island and Newfoundland and Labrador will suffer more socially vulnerable losses due to their relatively high dependency on shellfish fisheries (Wilson et al., 2020, p. 1). They used a biophysical model to investigate how climate change and ocean acidification might driver the future availability of shell fisheries resources. The data below shows the average annual value of the top seven shellfish species between 1991-2010.

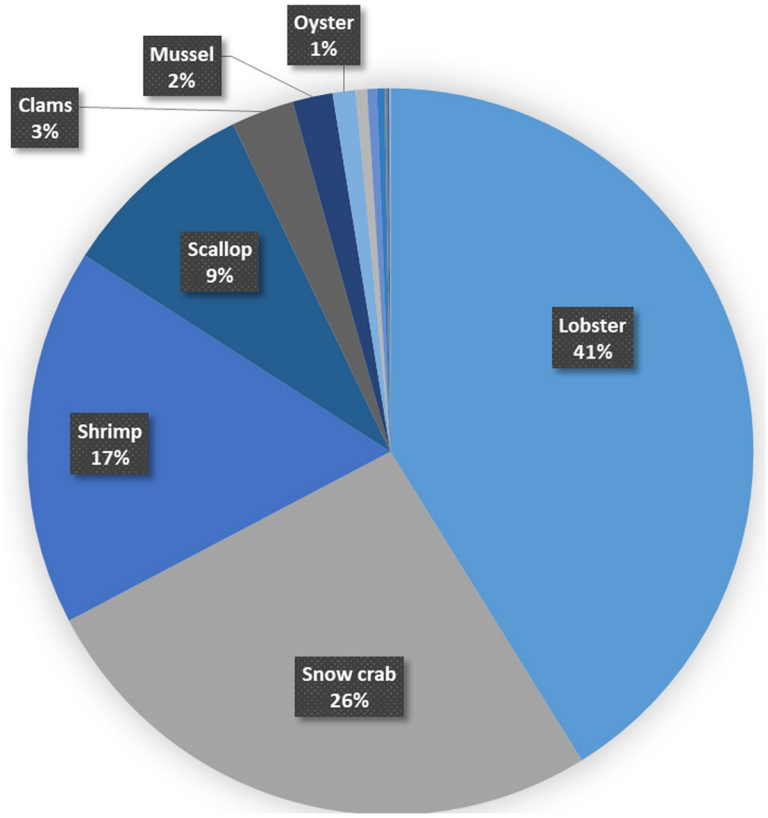

Figure 1. Breakdown of total shellfish annual landings value in Atlantic Canada

Any changes in landings of any type of the shellfish is likely to impact Atlantic Canada fisheries sector. Climate change and specifically ocean acidification affects all species leading to modest increases in landings in some areas and exacerbated declines of nearly 50% in others by 2090 (Wilson et al., 2020, p. 13). New Brunswick communities that are particularly reliant on fisheries are most at risk of the impacts of climate change. The provinces of PEI and NL are also generally at high risk with expected moderate to high impacts in social vulnerability. Nova Scotia has found to have relatively low vulnerability and capable of adapting to changes in shellfish availability in the region (Wilson et al., 2020, p. 22). This is however based on provincial statistics which do not put into consideration the vulnerability of the province in that it has a high rural populations and communities which are reliant on the fisheries sector. Further investigation will help to measure risk and the development of adaptation strategies to help prevent economic impacts, loss of income and possible food insecurity in the future (Wilson et al., 2020, p. 23).

Lam et al. (2016) argued that there is very little research and understanding on the economic impacts of climate change to fisheries revenue. They advocated for the development of socio-economic and food sustainability strategies to mitigate and adapt to climate change. Their study sought to understand the potential economic impact of climate change by focusing on the modelling of the effects of climate change on revenues through changes in the amount and composition of catches (Lam et al., 2016, p. 1). The price dynamics and the interplay between demand and supply as well as changes in consumer preferences could affect future seafood prices (Liam et al., 2016, p. 2). Climate change may positively or

negatively affect catches of certain fish species leading to increased market prices. The result of their study found that climate change will have negative impacts on the world's fisheries especially in coastal countries that are dependent on fish catches as a main source of protein (Liam et al., 2016, p. 5). A decline in fish catches will impact revenues and have large implications for the overall economy, reducing sectoral contributions to GDP in countries with high fish exports and which rely on fish tourism. For example, Atlantic Canada, specifically Nova Scotia is well known worldwide for its shellfish, a decline in these catches could impact tourism, affect the overall economy and possibly lead to future food insecurity (Liam et al., 2016, p. 5). The results of the study indicated that regions that are reliant of fisheries revenue have limited adaptive capacity to the effects of climate change hence the need for the building of resiliency and adaptive policy to deal with this.

Greenan et al. (2019) conducted to study climate change impact assessment using a geographical perspective based on the management units of American lobster in Nova Scotia. Their analysis was based on coastal vulnerabilities to climate change (physical environment, socio-economic and infrastructure) as well as responses to possible increases to ocean temperature. Ocean temperatures in southern Atlantic Canada have increased over the past century resulting in biological impacts that vary regionally and by fish species (Greenan et al., 2019, p. 2). Many Atlantic Canada rural communities rely on lobster for their economic well-being, however, as global warming continues, it is possible that some shellfish species like lobster may disappear while others may flourish, and this could have major impacts on commercial fisheries. (Greenan et al., 2019, p. 2). In 2016, American lobster contributed 44% of the total commercial value of fisheries in Atlantic Canada and lobster landings have been on the rise in the last few decades. Ocean temperatures above optimal thermal range reduce lobster survival, growth and lead to increased risk of disease (Greenan et al., 2019, p. 2). The results of the study concluded that Atlantic Canada is currently experiencing increased water temperatures although offshore lobster is not imminently vulnerable to the changes (Greenan et al., 2019, p. 14). Increase in water temperatures could, however, create longer fishing seasons with proportionally high fish landings which could lead to overfishing. They further emphasise how other factors could impact lobster populations such as ocean acidification, environmental degradation and the presence of invasive species which could affect lobster population and mortality (Greenan et al., 2019, p. 15). Emphasis is on the need for costal planning and adaptation for effective fisheries management as well as responsiveness to vulnerabilities that could result from declines in lobster and other shell populations.

Eide and Heen (2002) affirm that global warming effects such as longer growing seasons, lower natural winter mortality may offset some negative factors such as changes in established reproductive patterns, migration routes and ecosystem relationships. In their research, they emphasised the importance of looking at risks from a holistic approach. This is because although climate change indeed is a pressing problem, there are other human activities that might have a more immediate impact on fish stocks and production (Eide & Heen, 2002, p. 262). In their study, they used two different models; ECONSIMP2 and AGGMULT to analyse the economic consequences of global warming on the Norwegian economy. The results of the study showed that although global warming may have a significant impact on the changes in catches, profitability of the industry, employment

opportunities, income and management changes could have an impact on the biological growth rates (Eide & Heen, 2002, p. 273; Watson et al., 2004).

Additionally, Vázquez-Rowe (2020) argues that there is an ever-growing amount of litter entering the world's ocean, littering from cruise ships, mismanaged waste, coastal littering and primary microplastics entering the ocean that have become an environmental concern. While global warming and the impacts of climate change are increasingly impacting the fishing industry, it is also important to note that human action is playing a significant role in threats against the environment and the future food security (Vázquez-Rowe, 2020, p. 3). Most extinction today in the marine environment is occurring at higher levels as a result of human activities such as overfishing and exotic invasions (Vázquez-Rowe, 2020, p. 3). Evidence has shown that plastics and other residues reduce the reproductive output of marine species (Vázquez-Rowe, 2020, p. 3). The sustainability of wild fisheries is largely compromised, hence, sustainable strategies in the fishing industry may help prevent food insecurity, particularly for coastal communities in the future.

In conducting the literature review, the focus on climate change as a major driver of fishery food insecurity is most emphasized. The researchers and agency reports such as the one from FAO do show how climate change is currently and most likely in the future, impact fish species leading to either a decline or an increase. There is also no clarity regarding which types of fish would be impacted the most and what this would mean for certain economies that rely on them for trade. Furthermore, some research has shown that climate change is not the only environmental impact that could affect fisheries, for example plastic waste and overfishing. What lacks in this research, however, is the interplay between climate impacts and human hazards and how policies should be cognizant of these from a holistic point of view (Hutchings & Ferguson, 2000). There is also discussions on ensuring community resilience by diversifying opportunities and the economy, however, there is no clear research and evidence on what types of diversifications would work best for these communities considering that each individual community has specific needs and this could mean significant changes to achieve adaptation and resilience. Although the impacts of declines and increases in fish species are discussed, there is very little research on the economic impacts, particularly in the demand and supply, prices as well as how this could impact trade and food security. More research is needed to determine just how much impact climate change has had more than the various human hazards which can be minimized through employing the right sustainable policies and regulations.

4. Analysis and Implications for Policy Development

The world population is expected to increase to about 10 billion by 2050 and this poses threats to food systems, including the fishing industry, as food demand and the consumption of fish and fish products are also expected to increase (Kawarazuka & Béné, 2010; FAO, 2018, p. 50; Greenan et al., 2019). There is an urgent need for the development of sustainable fisheries management, effective monitoring and regulation as well as the development of resiliency strategies in order to adapt to the population increase as well as the effects of climate change (Marine Stewardship Council, 2019). Wilson et al. (2020) advocate for a global effort to reducing the impacts of climate change through reductions in carbon emissions and local policies that should also be adaptive to reducing ecological impacts.

Furthermore, they argue that improvements in education rates in these regions could help alleviate some social vulnerabilities by making available other employment opportunities outside of the fisheries sector (Davies & Brillant, 2019; Wilson et al., 2020, p. 23). Provincial unemployment rates should be addressed to reduce vulnerabilities resultant from declining fisheries.

The 2015 Paris Agreement recognises the need for effective and progressive responses to any urgent threats of climate change through the implementation of various mitigation and adaptation measures. The Agreement sets out clear goals for 'enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change' (FAO, 2018, p. 536; Shin, Conrad, & Lawell, 2019; Gordon, 2020). This includes the consideration of vulnerabilities in the food production systems, including the fishing industry. Efforts to minimize impacts to the fisheries and aquaculture sectors are a result of a lack in research and targeted analysis of the vulnerabilities within this sector. Efforts to adapt and mitigate against climate change should be human centred and these should be focused on poverty eradication and eradication (FAO, 2018, p. 19).

Having assessed the above literature, climate change will impact fisheries, communities and economies differently hence the need for targeted policies that will support adaptation and mitigation. Climate change adaptation and resilience building must be multi-sectoral and multi-dimensional so that those who are impacted the most can be able to recover and sustain themselves in the long term. Policies should aim at ensuring sustainable management of the capture, production and trade of fish and fish products (Packer et al., 2019). Many countries have taken pro-active actions to limit the greenhouse gas emissions, however, the reluctance of some countries, combined with the increasing global temperatures could setback all efforts.

Chapter 25 of the Fisheries and Coastal Resources Act of 1996 is the primary legislation that guides fisheries and aquaculture, including harvesting, recreational fishing, buying, processing, training and development in Nova Scotia. Section 10 (2) of the same act stipulates that the Minister may develop policies, standards, guidelines and objectives to meet the goals and purposes towards which fishery and coastal zone aquatic resource development and protection efforts of government are directed, including procedures, practices and methods for monitoring and analysis (Fisheries and Coastal Resources Act, 2019, p. 9). As such, the sustainability and adaptive efforts to the impacts of climate change will start with the development of concrete policies and regulations that will not only minimise greenhouse gas emissions but also limit human generated hazards such as plastic pollution and overfishing. There are numerous other policies and regulations that are relevant to fisheries and are likely to be impacted by climate change and may be revised for compatibility with sustainability efforts. The Health Protection Act outlines safety requirements for food handling and considering the likely changes that could occur to fish species, food safety and handling guidelines will have to be revised (Department of Fisheries and Aquaculture, n.d.). The Maritime Provinces Fisheries Regulations governs recreational fish species and as the population of some fish species declines or increase, this could impact the amount of fish that can be caught, where and how. The Sportfishing Licencing Regulations provides guidelines for the licencing of sportfishing in Nova Scotia and with efforts to reduce overfishing,

regulations may be reviewed (Department of Fisheries and Aquaculture, n.d.).

5. Recommendations

1) Improved research funding on the impacts of climate change to fisheries and economies.

Very little research has been conducted on the consequences of climate change to economies, particularly how changes in demand could impact market prices (Wang et al., 2019). Knowledge on the impacts of climate change to fisheries and the aquaculture will enable the generation of adequate policies and strategies that will benefit fishers, fish farmers, communities and governments in the sustainability of the fish industry in the long-term. There is a need for further research on best practices and strategies for reducing fishing pressure, strengthening economies and improving food security for communities that will be impacted by global warming and other effects of climate change. Furthermore, government(s) should invest in innovative technologies that will help inform risk and in the development of mitigation strategies to reduce vulnerability.

2) Implement policy measures that will address current and future threats in fisheries

Climate change is challenging the effectiveness of existing policies and management of fisheries and aquaculture. Climate change adaptation begins with the assessment of current strategies that will assist to build resilience of fishing communities as they adapt to the effects of climate change. Climate change is also changing food safety requirements and assessments as governments now have to deal with emerging food safety hazards and how these can be incorporated into existing policies and fishing regulations. The development and implementation of international standards will help reduce risks and impacts to fisheries (FAO, 2018, p. 535; Holsman et al., 2020). Measures should seek to help estimate future environmental variability, stock growth as well as the reproductive and mortality rates of fish species. The adoption of measures focused on the adoption of climate friendly methods in fisheries and aquaculture will help reduce the carbon footprint within the sector. These include adoption of fuel friendly fishing, production and distribution methods. Furthermore, enhanced emergency preparedness and response for the fisheries sector is a must for long term sustainability.

3) Reduce non-climate stressors which inhibit the resilience of fish species

This includes adjusting fishing quotas to help sustain stocks and relieve pressure on vulnerable species. As shown in the literature, global population growth has led to increased demand for fish and fish products and this has precipitated overfishing. Policies should seek to regulate fishing activities, particularly the extended fishing seasons resultant from climate change. Limiting plastic waste and the effective reduction and management of plastic waste will help to limit and eliminate the amount of plastic that ends up on the oceans. Many jurisdictions have implemented policies for the reduction and elimination of single plastic use; however, more can be done. Also, coastal communities should conduct cleanups of the beaches to prevent any plastics from entering the ocean(s), disrupting the coral and ocean ecosystem.

4) Diversify fisheries and sources of livelihood for at risk communities

While improvements in policy and fisheries management could lead to better outcomes, the impacts of reduced fishing will vary between fishing and fish farming communities and

industry based on exposure and vulnerability. Communities that are fish sector dependent will be the most impacted. While the impacts of climate change cannot fully be prevented, preparedness and climate resilience strategies could help sustain fish dependent communities. Creation of alternative employment and livelihood opportunities will help address these risks. This includes investments into education and technical training to enable alternative employment opportunities.

6. Conclusion

Research has shown that climate change will have a significant impact on the fisheries and aquaculture industries as global warming intensifies. This will affect fish species in the reproduction, mortality as well as susceptibility to disease. Communities that rely on fishing for income and for food security such as PEI and Newfoundland. will be the most impacted, hence, there is need for governments to take proactive steps in the formulation and implementation of sustainable policies and regulations for the effective management of this sector. Actions must also include the diversification of the sectors and investment into education and other skills building to adapt to changes as they come and ensure resilience of impacted communities and economies. While the impacts of climate change cannot be understated, it is important ensure that policies can also be applied to other human centered activities such as population growth, overfishing and plastic waste that could impact fisheries. Further research on the long-term economic impacts of climate change on fisheries is needed.

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