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AS PERCEPÇÕES DOS PESCADORES SOBRE AS MUDANÇAS CLIMÁTICAS: UM CASO DA REGIÃO DO NIÁGARA, CANADÁ

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FISHERS' PERCEPTIONS OF CLIMATE CHANGE: A CASE FROM NIAGARA REGION, CANADA

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RESUMO

As alterações climáticas podem resultar em impactos consideráveis em diferentes ecossistemas, incluindo ambientes de água doce. Elas podem também gerar consequências para as populações humanas e a economia relacionada aos recursos naturais, tais como a pesca comercial e recreativa. O conhecimento tradicional dos habitantes de uma região pode ser uma grande fonte de informação. O objetivo deste estudo foi avaliar a percepção dos pescadores locais sobre as alterações climáticas na região do Niágara, concentrando-se no Lago Ontário, Erie, e no Rio Niágara. Para isso, foram realizadas 20 entrevistas semiestruturadas com os pescadores da comunidade. Os resultados foram codificados através do software QDA Miner e avaliados por análise temática. Os pescadores notaram diferenças na abundância e tamanho dos peixes ao longo dos anos. Além disso, as primeiras percepções do grupo sobre as flutuações climáticas se relacionaram com os aspectos físicos da água, sendo o nível da água considerado mais elevado do que o normal pela maioria dos entrevistados. Percepções sobre espécies invasoras e outros problemas ambientais não diretamente relacionados ao clima foram mencionadas, além de ações de mitigação e adaptação ligadas ao tema. Pode ser observada uma significativa percepção por parte dos pescadores da região do Niágara sobre aspectos relacionados com as alterações climáticas e outros problemas ambientais. Este estudo fornece uma base de referência para ajudar a informar as decisões políticas e a sociedade em geral que possam ser necessárias para enfrentar os impactos das alterações climáticas e apoiar o desenvolvimento de estratégias locais de adaptação.

Palavras-chave: Clima. Pescadores. Alteração. Tempo.

ABSTRACT

Climate change can result in considerable impacts on many ecosystems, including freshwater bodies. They can also have consequences for human populations and resource-related economy such as commercial and recreational fishing. The traditional knowledge of the people from a region can be a great alternative source of independent information. The aim of this study was to assess small-scale fishermen's perceptions of climate change in the Niagara region, focusing on Lake Ontario, Erie, and the Niagara River. For that, 20 semi-structured interviews were conducted with fishermen in the community. Results were coded using QDA Miner software and evaluated by thematic analysis. The fishermen noted differences in fish abundance and size over the years. In addition, the group's first perceptions of climate fluctuations were related to the physical aspects of the water, with the level being considered higher than normal by most respondents. Perceptions about invasive species and other environmental problems not necessarily related to climate were mentioned, also mitigation and adaptation actions linked to the topic. Therefore, a significant perception by fishermen in the Niagara region of aspects related to climate change and other environmental issues can be observed. This study provides a baseline to help inform policy decisions and society at large that may be needed to address climate change impacts and support the development of local climate change adaptation strategies.

Keywords: Climate. Small-scale fishermen. Changes. Weather

SUMÁRIO

INTRODUCTION

Climate change has led to an increase in the frequency and intensity of extreme events such as heavy rainfall and droughts, resulting in considerable and sometimes even irreversible impacts on many ecosystems. This includes freshwater lakes, which are known to be very sensitive to climate fluctuations (Woolway et al. 2020). When it comes to the biodiversity's conservation and ecosystem services, understanding the resilience and vulnerability of lakes to climatic and environmental changes has become an important line of investigation (Angeler et al. 2015).

The aquatic communities and their food webs in freshwater ecosystems can be affected by long-term changes in climate in two ways: directly, through climate-induced changes in the abiotic components such as water temperature and ice cover; and indirectly, through changes in the biological components such as invasive species and diseases (Abdel-Fattah, 2016). For example, increased water temperatures may result in changes in the distribution of freshwater species and affect the community composition and food webs. With extreme heatwaves, especially in shallow lakes, the mortality rates of local fish can drastically increase (IPCC, 2022).

In the Great Lakes, known to be the largest group of freshwater lakes on Earth by total surface area, several studies have shown different effects that climate change has had on the freshwater basin (Alofs et al. 2014; Eimers et al. 2020; Gwendolyn et al. 2020; Wang et al. 2018). Aspects related to water physical features, biodiversity, increase of invasive species, algal blooms, and changes in fish populations demonstrate the vulnerability of the Great Lakes' aquatic ecosystems. It is important to continue these studies for greater knowledge and future projections (ELPCP, 2019).

In the Niagara Region, Ontario, where two of the five Great Lakes are located (Lakes Ontario and Erie), the local average annual temperature has already increased by 1.3ºC over the past 40 years (Penney, 2012). According to future projections, in higher emissions scenario, changes in the temperature for 2030 and 2050 time periods are 3.3º and 5.5º in the region. In addition, precipitation is expected to increase by 4% and 6.2% and the number of days with a freeze-thaw cycle is projected to decrease from 76.6 days to 67.4 over the same period. The projections then suggest that more precipitation as rain and less as snow during the cold seasons may lead to increased flood risks in the region (ELPCP, 2019; TRCA, 2022)

Such changes would also have consequences for human populations, especially regarding natural resources such as commercial and recreational fisheries, ranging from small subsistence efforts to large commercial ventures (Ficke, 2007). In the Great Lakes, recreational fishery is worth more than $13 billion (Badawey, 2020) and provides ecosystem services values ranging from $0.3 to over $1.0 billion per year (ELPCP, 2019). In Canadian provinces and territories fisheries contribute a total of $7.9 billion to various economic sectors in 2015 and, in Ontario, this is related to over $230 million a year to the economy regarding commercial fishing (DFO, 2022). Therefore, the evolution of aquatic systems under climate change, which could be nonlinear, complex, sudden, and possibly not reversible (Isaak and Hubery, 2004), can have implications for the fisheries throughout the value chain (Barange et al. 2018).

While projections coming from global circulation models (GCMs), integrated numerical modeling, annual reports, and other computer technology are widely used, they often do not depict the changes at the local level. Acquiring information in communities can help broaden our understanding of their knowledge and perceptions regarding climate change and its impact on their local activities such as fisheries. Local ecological knowledge from people of a region can be a great alternative and, when combined with scientific data, provide independent sources of information (Roux, 2018). That said, understanding the future responses of small- and medium-scale fishing communities to climate impacts requires information on how they perceive these changes. They often base their understanding on local ecological knowledge systems and in this way strategies can be created to support their adaptation, among other measures (Dannevig and Hovelsrud, 2016; Mazzochi et al. 2020).

Interviews are an effective technique to acquire information from local people. They also make it possible to investigate a community's perspective on what is important or relevant, thus potentially highlighting issues, perceptions, viewpoints, values beliefs, or decision-making of stakeholders that other scientific knowledge may not consider (Young et al. 2018). Yet, there has been few studies on the views of the fishing community towards climate change in the Niagara Region.

Therefore, the aim of this study was to assess what are the small-scale fishermen's perceptions of climate change in the Niagara region, focusing on Lake Ontario, Lake Erie, and the Niagara River, which are considered important fishing spots in the region. We aimed to analyze: (1) what personal observations fishermen have about fish and how they relate this to climate; (2) what climate

variations have they observed over the years; and (3) what general information about adaptation and mitigation measures fishermen in the region have in the face of climate change and other secondary environmental impacts that may occur in fisheries. We expected that depending on the importance of fishing activity in fishermen's lives, their perceptions of changes that may be related to climate fluctuations in the region would vary.

METHODS

Study Area

The Niagara region is located in southern Ontario, Canada, and is bounded on the east by New York State, USA, and on the west by the city of Hamilton (43.0582° N, 79.2902° W) and is located between Lake Erie to the South and Lake Ontario to the North, and by the west to the Niagara River (Figure 1). The Niagara Peninsula watershed supports 520,000 people and 15 municipalities with 30% natural cover, providing biodiversity benefits for the region (NPCA, 2021).

Lake Erie has a surface area of 25,655 km² and a watershed population of approximately 12.4 million inhabitants, mainly in the United States. It is the most southerly, shallow, warmest, and biologically diverse of all of the Great Lakes, supporting one of the world's largest and most valuable freshwater commercial and sport fisheries (Reutter, 2019). Ontario's commercial fishery is mostly focused on Lake Erie, where walleye and yellow perch account for most of the catch (Ontario, 2019).

The Niagara river constitutes part of the international boundary between the United States and Canada and is the major connecting waterway between Lake Erie and Lake Ontario. It is approximately 58 km long, flowing with a drop at one of Earth's natural wonders, Niagara Falls, an important hydroelectric and touristic spot. Niagara River provides fresh water for approximately one million people and at least 41 species of fish are known to spawn in its waters (Ramsar, 2019).

Lake Ontario has a surface area of 19,009 km² and a watershed population of approximately 9 million inhabitants. It is the last lake of the Great Lakes before getting to the St Lawrence River and gradually the Atlantic Ocean. It is therefore a strategic corridor for transportation, water

exchange, and fish migration. Although it is the smallest of the Great Lakes, more Canadians live in the Lake Ontario watershed than any other watershed in the country (DFO, 2015).

The local water level is managed by the government hydrological control in the region, trough the International Joint Commission (IJC) regulations and plans. The water levels are determined by water supply balanced against water outflow. The water that comes to the lakes is primarily from water flowing from the other Great Lakes and secondarily from precipitation and runoff from the surrounding watershed, minus evaporation and water releases though the dams (GAO, 2020).

Niagara region fish communities provide a diverse range of year-round recreational, commercial, and First Nations fisheries. The fishing industry and leisure play a very important role in its economy, with most of it coming from commercial fisheries, boat rentals for tourism, sport fishing and ice fishing in the winter. All types of fishing follow government regulations, including licenses, fishing seasons, catch limits, and fishing zones (Ontario, 2019).

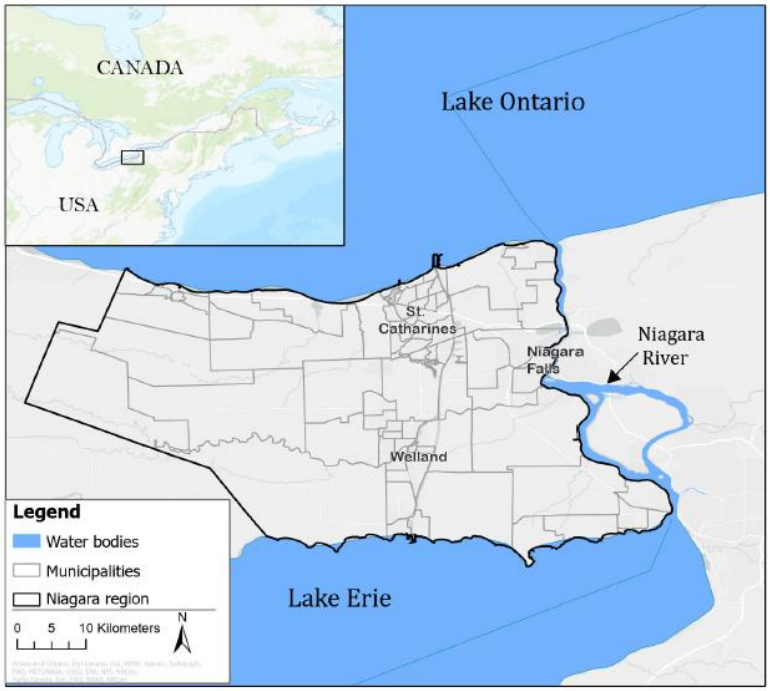

Figure 1. Map of the Niagara Region. (Own representation. ArcGIS software, 2022)

Data collection

For this study, 20 semi-structured interviews were conducted between March and April of 2022 according to the interview guide (Appendix S1). To identify possible interviewees, we initially consulted the Internet and groups/organizations that were related to the industry. With institutional review board approval from the Brock University Research Ethics Committee (REB #21-190), we invited the fishers for the interview through email, text or social media. Prior to the interview, Consent Forms were signed by all fishers. The interviews were conduced online, following the government Covid-19 restrictions at the time, through the MS Teams Meeting platform or by phone call when requested by the fisher, and lasted up to 45 min. Two of the interviews were conducted by email. Anglers' selection did not follow any exclusion criterion, as any interested anglers who fish in any of the three main fishing spots in the Niagara region were included, regardless of experience or type of fishing.

Data analysis and statistics

The audio-recorded interviews were transcribed and the fishers' name were replaced by numbers to preserve the identity of the individuals. For further analysis, the types of fishing considered were recreational, commercial, or both. The recreational fisher was considered as a fisher that fishes for sport, pleasure, or personal use, and not doing commercial fishing activities. On the other hand, commercial fisheries were considered as those that have a fishing business renting boat trips for tourism, guiding, or sales, meaning that the fishing activities contribute to their income, so the fishers in some degree depend on fishing for their livelihoods. The fishermen were also classified according to their fishing location, style, the richness of species caught, and what limits them to carry out their fishing activities.

Thematic Analysis, used in qualitative research, as it has been suggested that can be a flexible and useful research tool and can provide a rich and detailed, and complex view of the data (Braun and Clarke, 2006). This type of analysis is also considered the most appropriate for any study that aims to discover using interpretations (Mohammed, 2012). It consists in creating codes and dividing them into themes to answer the typical generic question, allowing one to see what is fundamental in the investigation (Paillé and Mucchielli, 2012). Thus, the thematic choice of the aspects chosen

in this investigation can be understood in a mind map (Figure 2), used to answer what are the perceptions of the fishermen of the Niagara Region.

To complement the analysis and to perform the statistics, we used the software QDA Miner, a qualitative analysis package for coding textual and graphical data in qualitative research that contained a "code sequencing" function so the thematic coding can be applied.

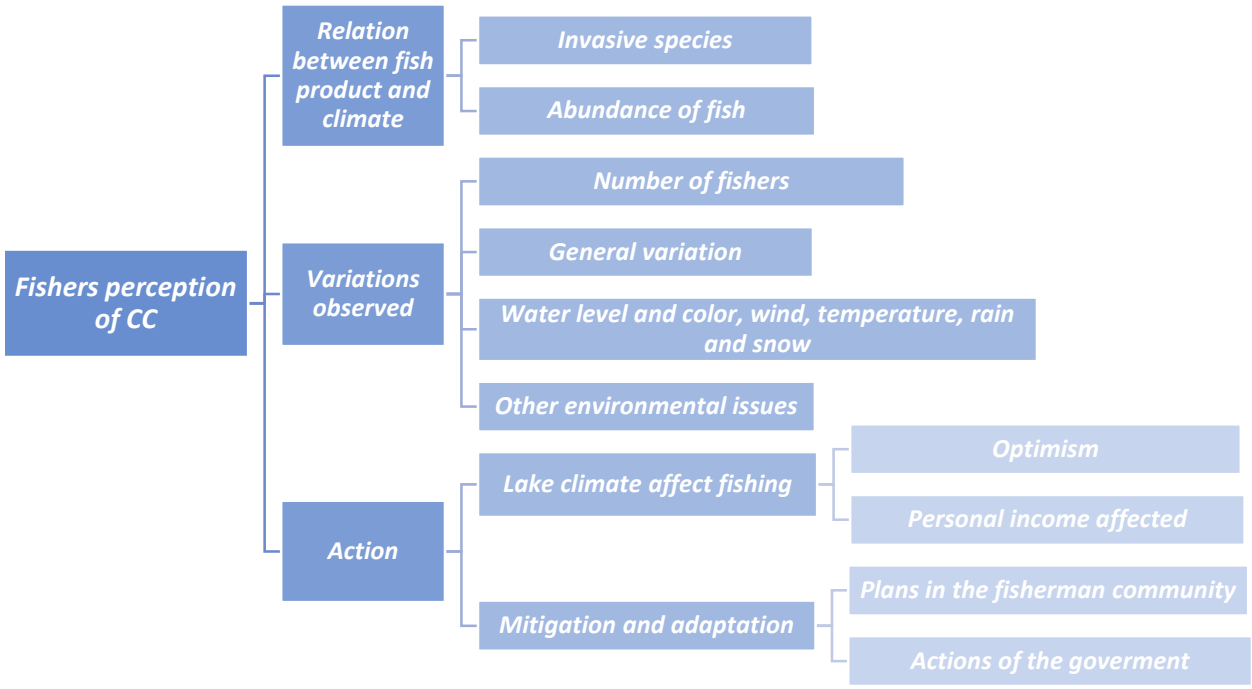

Figure 2. Thematic coding division of the fisher's perceptions of climate change in the Niagara Region

RESULTS

Characterization of the fishing community

Of the 20 fishermen interviewed, all of them fished in Lake Ontario, 11 fished in Lake Erie, and 8 fished in the Niagara River, with 13 of them fishing in more than one of the three places mentioned above. Half of the anglers fished for sport, 35% fished for sport and commercially and 15% only

commercially. The fishing style of all fishermen was by boat, of which 55% also fish for the shoreline. More than half (11/20) of the fishermen reported fishing for five or more species in the region. Most interviewees mentioned being a member or having contact with an association or committee related to fishing and information dissemination in the region, such as St. Catharine's Game and Fish, Niagara River Anglers Association, Lake Erie and Ontario Committees, among others. They also have been fishing from generation to generation. The weather was the main limiting factor in their fishing effort, behind other work and personal time.

Perceptions about the fishing product and its relations with climate change

Of the fishermen said that they noticed changes that they assumed were climate-related, 45% said they noticed a decrease in fish populations, 35% said they noticed an increase, and 20% said populations of fishes, in general, remained the same over the years. The main species reported were the Rainbow trout (*Oncorhynchus mykiss*), Chinook Salmon *(Oncorhynchus tshawytscha*), Yellow Perch *(Perca flavescens*), Smallmouth Bass (*Micropterus dolomieu*), Alewife (*Alosa pseudoharengus),* Atlantic Salmon (*Salmo salar)* and Walleye *(S. vitreus).*

One-fifth of the fishermen said that they had observed fish sizes, in general, to have increased in recent years, with Smallmouth Bass (*Micropterus dolomieu*) and Chinook Salmon *(Oncorhynchus tshawytscha*) populations specifically mentioned in this context. However, a general decrease in fish size appeared in 45% of the interviews, with species like the Yellow Perch *(Perca flavescens*) being cited.

Observed variations

First, the fishermen were questioned about the general changes they observed over the years in the fishing places, without being induced to answer about a particular category. Their responses were then divided into four categories, according to the type of changes they cited as being foremost in their perceptions and then differenced between the reason for fishing. For the recreational fishers, only one said not observing any general variation about changes in the climate (Figure 3). More than half of the fishers mentioned that changes in the climate could affect their income (in case of

the commercial ones) or their fishing activities (in case the recreational). However, such changes were reported especially by commercial fisheries, 75% of which reported that the climate variations can affect their fishing.

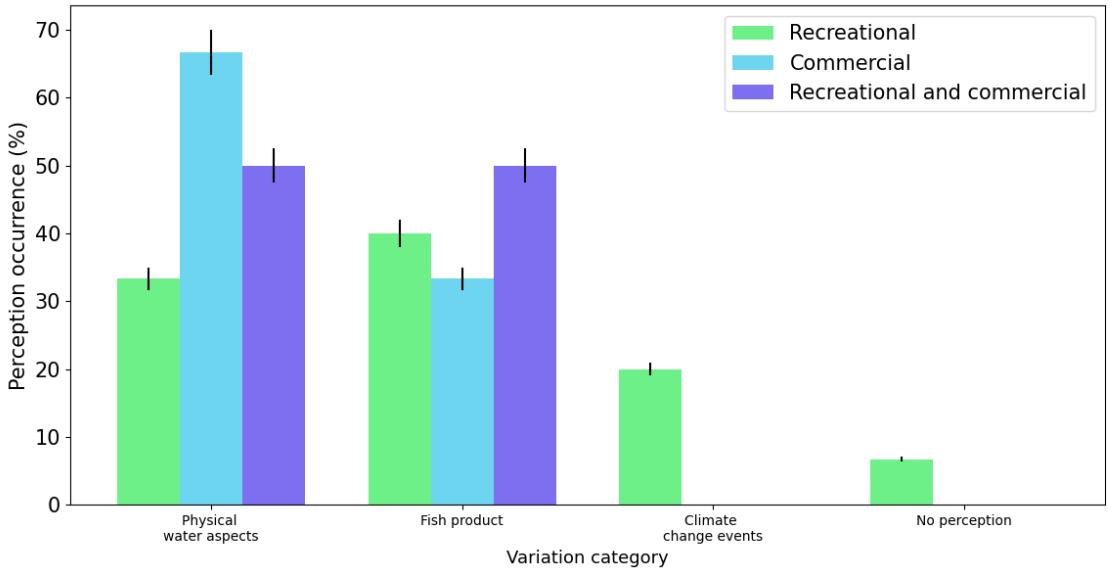

Figure 3. The general perception is categorized and observed by the type of fisher in the Niagara Region.

When asked about which specific changes they thought to be climate-related, the fishermen reported nine different aspects. However, these aspects were not necessarily related to climate change (Figure 4).

Concerns about invasive species appeared in 85% of the interviews. When approached about which species they observed as invasive, six were the most reported (Figure 5), with the Goby fish *(Neogobius melanostomus)* being the most mentioned, appearing in 60% of the answers.

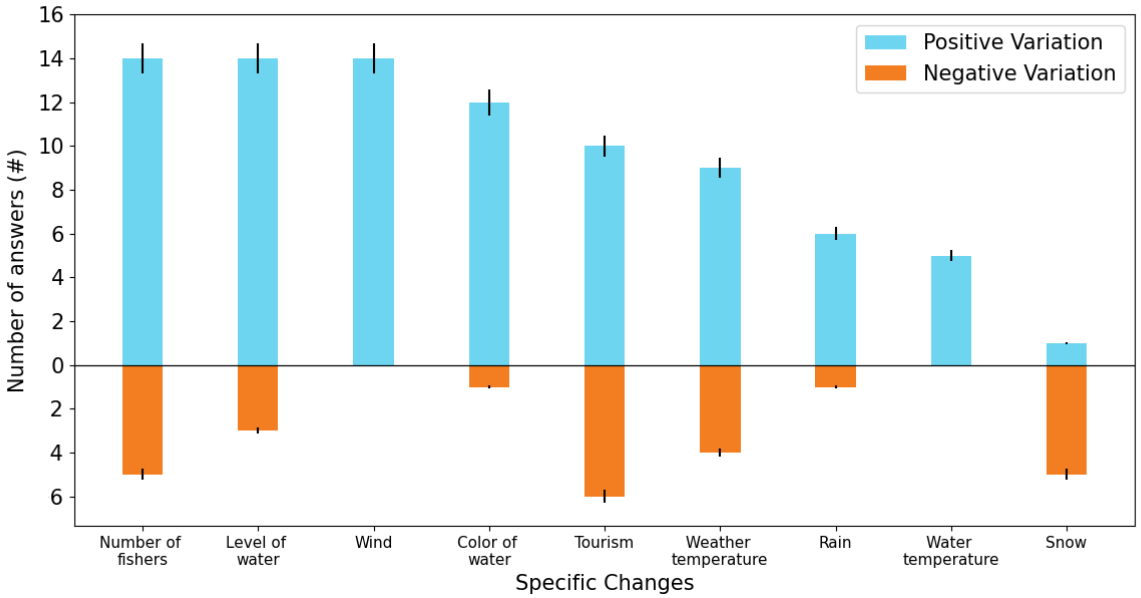

Figure 4. Specific variations noted by fishers from the Niagara Region over the years.

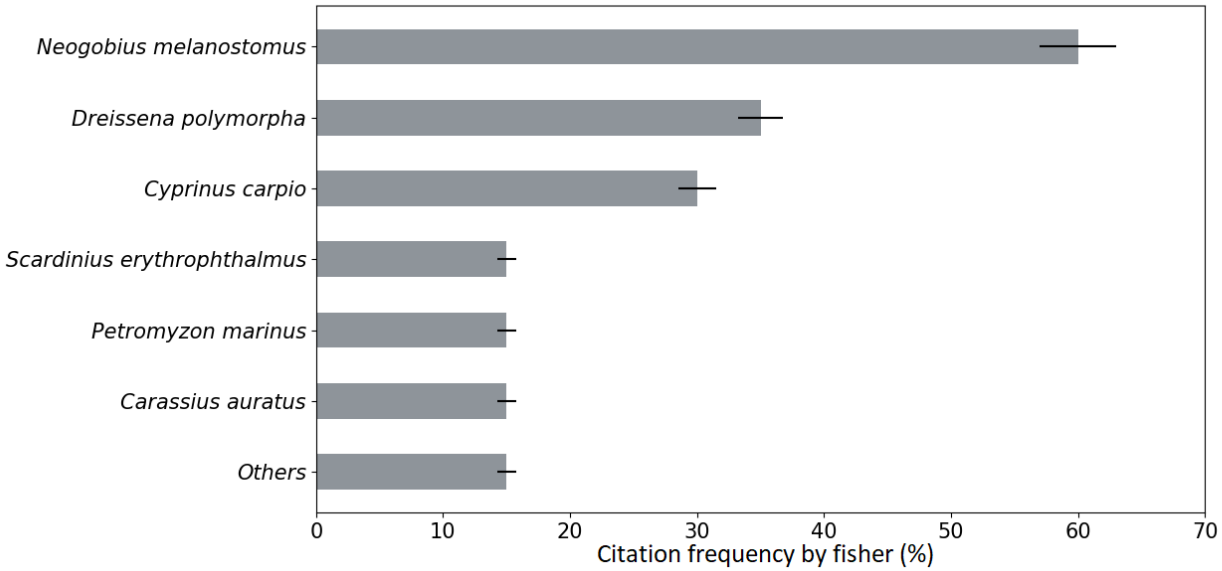

Figure 5. Invasive species mentioned by fishers in the Niagara region

Although not directly related to climate change, other important concerns raised, which could be linked as a side effect of the theme were compiled in this work were: pollution and the presence of

garbage in the environment along the lakes and rivers (5/20), the presence of diseases in fish relating to viruses, worms, tumors and vitamin D deficiency (6/20), the increased presence of Cormorant birds (2/10), and algae bloom events (2/10).

Actions

Some actions related to climate change mitigation and adaptation were already being taken by the fishing community of the Niagara region. Ideas and suggestions emerged about other actions that could be taken on this environmental theme and others, all indicated by different fishermen (Table 1).

Table 1. Actions already taken in the fishing community and ideas for new actions regarding adaptation and mitigation to climate change.

Plans taken to adapt to changes in the climate and reduce the risks of events	Ideas for adaptation and mitigation actions
"They have tried to limit their waste, limit their trips to the water, even they try not to fish every day…. They'll limit themselves to every other day just from a **carbon footprint** point of view."	"Fishing for different fish or **going to new places**, there's always a way to adapt."
"**Associations and initiatives** wanting to help that and keep the fishery going. Also, v**olunteer groups and fishing communities** all around Ontario that get involved and help."	"If the water levels go up or down, you just have to go further south of the lake or you just have to find the **different ducks in the lake** where you would fish for these fish."
"A lot of guidest that have downsized their vessels have been more agile, being able to depart from **different locations** and provide **a different style of angling** opportunities."	''**Stricter regulations on emissions from major companies, and manufacturers in first world countries** will have a much faster impact. Nuclear energy is likely the best answer"
"**Educating** the kids about this. [...] **Cleaning** the water yourself. [...] Be natural if you can instead of plastic. "	"It's about **teaching people what not to do and control.** For example, I'm a big advocate of us being allowed to fish five salmon per person. It's about controlling limits."

“**Researches** like this one. [...] Fishing with our environmentally conscious and try to not waste and to fish with **burning as little gas as possible**. I try to use our electric motors more often, and we're always trying to drive our boat farther than we have to, to minimize driving time."	“**Electric vehicles, cleaner energy sources** instead of coal and oil such as nuclear, reduction in pollution from large companies "
“Education and also **rearing, helping** rear fish to kind of sustain the population. It's more helping sustain populations of fish and help educate and bring **awareness** to industries to the young generations."	"We have to lower our **carbon emissions**."
"We try and volunteer time or **raise money** for the clubs to kind of sustain the fishery"	“Better spend their time and money and efforts on **habitat improvement projects**. If we know where the fish are spying, we can kind of make sure we're putting the resources at those locations as opposed to just making guesses.’’
“There are some associations that do a lot of **planting of trees and shrubs** to keep the temperatures lower. And they have seen a huge success in keeping the latest on the credit over the past 30 years is they've brought the temperature down by over 5 degrees. They also do clean-up days on the rivers or riverbanks. They do a **revitalization** on the rivers"	"It's an **awareness exercise for land owners and municipalities** talking to land owners"
“They're doing telemetry and putting beacons in the lake, and they're tagging fish, and they're c**ollecting all this great amount of data** in terms of fish movements"	“Through the **binational type management** that we have right now with New York State. Utilizing science serving, creel, census, things like this, the more data the better.’’
“I see more **government funding** for research into the things like algae blooms which is in some ways is caused by climate change."	“More **accurate measurements of bait fish populations**, and specifically alewife populations’’

Source: From the author (2022)

Furthermore, the group was asked about their perceptions of the role of government and public agencies in helping the fishing community prepare for climate change and extreme events to ensure that fishing can continue. The cited words that relate to their perceptions were best exemplified in a word cloud (Figure 6). The most relevant and abundant expressions in the fishermen's responses were related to people, government, lake, change, education, kindness, impacts, meetings, settlement, Ontario, and others. Moreover, 65% of the fishers said they're optimistic about their future and the future of the environment despite climate change.

Figure 6. Words most frequently said by fishermen when asked about government actions

DISCUSSION

Fishing community and its relation with climate change

Recreational fishing is the best-known type of fishing in Canada and Ontario is the most popular province for sport fishing, being sought after by more than half of anglers in Canada and Quebec bring second (DFO, 2015). In the Niagara region, sport fishing is present in much of the lives of

most fishermen and is passed down from generation to generation, even those who also fish for subsistence:

> Fisher 17: " [...] Fishing is a passion of mine and its kind of a great way of kind of getting away from the day-to-day stress."

The presence of scientific outreach organizations and meetings may be one reason why commercial fishermen more often consider climate change affecting their fisheries. By coming into contact with the effects and changes in the climate, they can see the difference it can make to their livelihoods, being more aware and in their minds because they want to be able to continue fishing for a longer period. Great Lakes fluctuations faced by climate change may interfere with the fishing communities that depend on them directly (ELPCP, 2019).

Interestingly, in this study, the physical aspects of the water and environment were the main focus in the general variations of changes observed by the fishermen. It is known that anglers are constantly experiencing changing weather / climatic conditions (Jahan et al. 2015). For them, the variations in the environment can be monitored by the simple act of going out to fish every day (Ford et al. 2006), even if it is for recreation or commercial purpose. In this sense, noticing the changes in the weather and physical water aspects with smaller time scales becomes easier to identify and have knowledge about. Weber (2010) explains that climate change cannot be easily identified by the lay public through their normal inference and observation mechanisms alone. He says that because the climate is a statistical occurrence, based on a long-term average, it cannot be detected by personal experience, although people often confuse it with weather events.

Furthermore, fishers can see climate change as a secondary risk to their business, especially when compared to other threats (Nursey-Bray et al. 2012). This might explain why this type of event was the category least talked about by the fishers. Still, perceptions about the other types of change can infer a lot about the community's knowledge of the region and help in future studies and predictions about climate. The fisher's first perception says a lot about how they relate to climate and how close they are to the subject in the region, although this could be also an individual perception, depending on many socioeconomic factors in their life.

Observed changes

Results on the climate change perceptions of the fishers showed that changes in the level of water, wind events and color of the water are the most observed. However, the most mentioned feature was the number of fishers in the region. Although not directly related to climatic events, the status of the fishery says a lot about the fishing demand of the region and the intensity of the fishermen's fishing effort. According to data collected by the U.S. Fish and Wildlife Service (2016), the number of anglers has increased over the last decade in the Great Lakes, but the reason for these trends is not clear yet. It is important to mention that the considerable increase in the number of fishermen in the region observed by the fishing community may also be related to the recent pandemic situation. With the restrictive measures, sport and commercial fishing, as practically individual activities, may have had greater freedom to be carried out, bringing greater interest from new fishers in the region. The environmental factors, however, cannot be ruled out as causal factors related to increased participation. However, the other aspects mentioned, in some degree, may actually be related to climate change.

In 2021, Lake Ontario's level increased by two cm in November, at a time when the lake typically declines by three cm. This is partly due to near-record-high inflows coming from Lake Erie (Environment and natural resources, 2021), what can explain why fishers are noticing an increase in the water levels. Besides that, water levels can be influenced by many other factors, including precipitation, snowmelt runoff, drought, evaporation rates, and people withdrawing water for multiple uses (EPA, 201) which are directly affected by climate change.

The effects of global warming on wind speed and windiness are uncertain at the regional or global scales (Pryor et al. 2020). However, the most recent report from IPCC forecast that, globally, the mean wind speed and directions will change depending on the region because of climate change (IPCC, 2022). Changes in the wind patterns can affect the ecosystem productivity and with that affecting the geographic range limits of northern and southern species (Poesch, 2016). Higher wind speeds, in turn, can happen due to an increase in air and surface temperatures and wind direction, what can lead to a greater evaporation rate, increased sedimentation in rivers and lakes and thermocline depth shifts (McDermid et al. 2015). This can directly affect fishers in their fishing effort and other economic reasons:

> Fishermen 7: ‘’ And I've noticed over the last, say, five to 10 years, there are a lot of really windy days where I can't get out. It seems to me like the storm."
>
> Fisherman 11: ‘’I'm gonna say the frequency of windy days is greater now than it used to be. So there are more intense winds now than historically. […] I won't be going out because the wind is blowing too high.’’

The characteristic of clearer water in recent years reported in the interviews was related, in most answers, to a consequence of the increased population of Zebra Mussels *(Dreissena polymorpha).* Indeed, this specie’s success is extremely related to increases in water transparency (Alexander et al. 2020). Besides that, the water transparency can also be related secondarily to other events like the increase of algae blooms and the intensity of the winds (Amorin and Moura, 2021). All these causes, in turn, are linked in some way to climate change, which demonstrates the importance of the perceptions given by fishers in this regard.

The range shifts that these changes in the climate can cause on freshwater fish may explain why the fishers mostly noticed differences in populations and size of the fish in waterbodies. Some fishers noted a greater increase in the body fish body size, while others mentioned that some species decreased in size, as was the case of Yellow Perch *(Perca flavescens*). Fluctuations in water characteristics, including temperature and physical components, can affect fish size distribution and species composition (Daga et al. 2012). For example, temperature increases has been linked to metabolic constraints leading to body size reduction in freshwater species (Poesch, 2016). Also for yellow perch, a northward range extension of 2º to 8º latitude are projected because of changes in lake temperature (Poesch, 2016).

In the context of fish abundance, however, fishers reporting a decline in species might be linked to recent years decrease in lake stocking. Lake Ontario, for example, is stocked annually by New York State and the Province of Ontario with over 6 million fish to control the populations and predator-prey balance (Ontario Ministry of Natural Resources and Forestry, 2015). However, North American freshwater fish populations have been changing poleward and upward in response to local and regional climate trends (IPCC, 2022). This, aligned with the stocking reduction by the governments (GLFC, 2018) and the spread of invasive species, could explain the decrease in some fish populations.

Exotic species are affecting the aquatics biodiversity and are considered the second largest cause of native species extinction in the United States (Mayfield, 2021). In the Great Lakes, the potential loss value for the threat of aquatic invasive species is a 4% loss of native North American freshwater species per decade through predation, overcrowding food web alterations, etc. (Krantzberg and Boer, 2006). These species are now expanding their ranges due to warmer temperatures and threatening the native ones (McDermid et al. 2015). The establishment of round goby *(Neogobius melanostomus)* has been facilitated by its prey presence, zebra mussels *(Dreissena polymorpha)* (Burgiel and Muir, 2010). This may explain the number of reports of these two species in Niagara Region. Furthermore, Asian Carp's scpecies are one of the fishers biggest concerns, since its populations continue to increase in the Great Lakes and are considered a risk of ecological impacts for other species (ACRCC, 2012). This group may be the one that currently poses the most imminent danger to Lake Erie (Reutter, 2019). This subject, therefore, needs to be looked at with caution, since climate change can act as an intensifier of the invasive species' spread, increase their competition with the natives' ones, facilitate their movements through extreme events, and shift its distribution ranges (Burgiel and Muir, 2010).

Intimacy of fishermen with climate change actions and information on the subject

The themes raised by the fishers about other environmental issues linked to fishing were associated as a side effect of climate change.

Over 460,000 plastic particles per square kilometer have been identified in Lake Erie and up to 1.1 million particles per square kilometer in Lake Ontario in 2014 (Mason et al. 2020). Also, weather conditions, such as greater rainfall events, can result in greater abundance of plastic debris reaching the lakes and rivers over shorter periods (Corcoran et al. 2015).

Studies on the presence of tumors and viral diseases in fish in Lakes Ontario, Erie, and the Niagara River warns about their potential effects on fish, fisheries in general, and the community that depends on this resource (Getchell et al. 2019; Visha et al. 2021). In addition, the Double-crested cormorant (*Phalacrocorax auritus)* has become a concern for anglers and commercial fishers in Ontario region from Great Lakes. Several studies have shown that cormorants pose no threat to the fishery since they can switch their prey sources in response to changes in fish species composition.

These birds are taking considerable numbers of invasive fish, especially round goby (Hobson, 2021). Although this was not the object of this study, these data can be used for other future studies that may want to deeper invastigate into these issues and demonstrate that perceptions may be related to individual skepticisms levels and self-interpretations of reality (Whitmarsh and Capstick, 2018).

Adaptation and mitigation are two relevant topics when it comes to communities' vulnerability to climate change. Even though they have fundamentally dissimilar approaches, they are interconnected and both are necessary for combating climate change (Kongsager, 2018). Barange et al (2018) explains that fishers are usually not heard in the climate adaptation planning process, which reduces their short and long-term resilience at all stages of the fisheries value chain, including the whole community.

In Niagara region, some adaptation and mitigation actions are already being developed and shared among the fishing community, as seen in this study. The actions related to mitigation are always taken to reduce the extent of climate change (Tompkins et al. 2013) and the ones related to adaptation are dealing with the consequences of it (Warren et al. 2012). However, the region still has insufficient actions by the government. Scientific and public outreach about what to do to adapt remains limited. As can be seen in this study, the fishers had many ideas about what can be done, but there is a lack of planning for these measures to be put into practice in the community.

CONCLUSION

Because we know that global warming is one of today's biggest challenges and has many facets, it must be addressed both globally and regionally, as was the case in this study. Although this was a small-scale study, it was possible to understand the fishing community's perceptions about climate events and how this affected their lives. It can be concluded that the fishing community of Niagara region has a good knowledge of the weather-related aspects of the region which, along with local

knowledge passed down from generation to generation, results in good observations about the weather and climatic conditions and the changes it undergoes over time.

This study provides a baseline to help inform policymakers and the broader society that may be needed to address the impacts of climate change. It can also build support for citizen science programs to improve data collection across the temporal time scales needed to observe climate change. Finally, it improves the interpretation of changes observed in recent decades and years and supports the development of local adaptive strategies to climate change.

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APPENDIX S1

Fishing scenario

1. Where do you fish?
2. Do you fish for sport (i.e., recreation), to make a living (i.e., for income), or to provide for your family (please indicate if more than one answer)?
3. Do you fish by boat or shoreline?
4. Do you always fish the same species? Which species do you fish the most?
5. When do you fish (time of day, day of week and season)? What limits you?

Changes in the lake over the years

6. Have you seen any general variation over the years? Why? Despite these changes (if any), do you intend to continue fishing?
7. What is your perception about the change of the following aspects related to the Lake over the years: (You can answer me in a few words)?

- Tourism
- Level of Water
- Number of fishermen
- Color of water
- Wind
- Temperature
- Rain
- Snow

8. Since you have been fishing, has there been a year that was notable for the greater or lesser number of fish? or for a specific species?
9. Do you think that small changes in the lake climate could affect your personal income in any way? And the local/country economy?
10. Have you seen different species arriving here at the Lake in recent years? (Potentially invasive)
11. Have you noticed any difference in the quality of the fish in the last few years? (e.g., size, health, behaviour, etc.)

Perception of the influence of climate change

12. Do you think that climate change has affected fishing activities?
13. Have you noticed in any year longer periods of drought or large rain events?
14. Over the years, have you observed any warmer or colder than normal periods?
15. Do you feel optimistic about the future of the environment despite climate change? [Yes/No]
16.

Adaptation to climate change

17. What do you think might happen in the next ten years to Lake Ontario/Eire?
18. How do you think these impacts can be mitigated?
19. Do you think you have the capacity to adapt?
20. In the group of the fishermen you know, are there plans to take actions to adapt to changes in the climate and reduce risks of events? (For example, floods, torrential rains, storms, etc.). What are they?

21. What do you think government should do to help your community prepare for changes in the weather and lake events predicted by climate change models to ensure fishing can continue?