Are The Fish Safe to Eat?

An Examination of Lake Nipigon Fish Consumption Guidelines Through the Perspective of Biinjitiwaabik Zaaging Anishinaabek

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Abstract

Mercury (Hg) is a contaminant of concern when consuming fish from freshwater lakes. It is known to persist in high concentrations in piscivorous fishes such as Walleye which are commonly consumed by people. The people from the community of Biinjitiwaabik Zaaging Anishinaabek (BZA) Rock Bay have harvested fish from the Lake Nipigon basin for millennia and have observed changes to the Lake, particularly those resulting from resource development and extraction. Large scale hydroelectric projects and mining have created concerns over the safety of eating Walleye in the Lake Nipigon basin from traditional fishing locations. While fish consumption guidelines are posted by the provincial government for certain areas, a lack of robust data, trust, transparency and communication about the risks of exposure to consumers has rendered these guidelines largely ineffective for community use. In this study, data collection was led by community fishermen to collect fish from traditional fishing locations to produce community driven fish consumption guidelines. In general, fish consumption guidelines produced from community sampling were less restrictive than those posted by the provincial government where comparable. However, community-based fish consumption guidelines were more restrictive in riverine environments than lake sampling locations. As a result of having engaged in data collection and monitoring for fish contaminants, BZA has developed greater trust and interest in fish consumption guidelines while greatly enhancing its lands and resources program to further study concerns on Lake Nipigon.

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To Ray Nobis who brought forward community concerns related to development around the lake and continuously stressed the need for Rocky Bay and its fishermen to be stewards of the lake and its precious fishery. And Tunny for sharing his vast knowledge on the history of the Lake Nipigon fishery, and its political influences.

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This thesis belongs to the community of Rocky Bay as much as it does to me, this work only captures a sliver of the massive effort put forward by our many partners to understand the health of the lake and what it means for the people who depend upon it.

And of course, my supervisor, and good friend Rob Stewart, for always providing strong support and pushing me outside of my comfort zone. To Nathan Wilson for guiding me through field work procedures and providing support throughout various research projects.

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Preface

Over the past four years I've had the pleasure of working with and for Biinjitiwaabik Zaaging Anishinaabek (BZA) as a researcher and coordinator to help develop their growing Lands and Resources monitoring and research programs. The community reached out to Lakehead University in 2016 seeking a partnership to explore their concerns related to contaminants in traditional food sources, looking to build on a previous study conducted by Nokiiwin Tribal Council and CanNorth Consulting. We set out to investigate these concerns surrounding the impact of development and the risk of eating food from the land, specifically fish. Over time, the project has blossomed into a basin-wide research and monitoring program with various organizational partnerships and members of the community taking part, including a newly created position within the community; the Environmental Guardian Monitor. The community-lead program has evolved using traditional knowledge, sediment cores, water quality and fish populations and contaminant data to investigate the changes on Lake Nipigon. This thesis focuses specifically on the fish mercury levels and fish consumption restrictions in the fishing grounds of Biinjitiwaabik Zaaging Anishinaabek. While I have worked closely with the community over the past few years, I am not speaking on behalf of the community in this thesis.

Chapter 1: Introduction

1.1 Background

The consumption of wild fish comes with many benefits which is especially true when considering Indigenous communities in Canada who consume fish from their traditional lands and waters (Turyk et al., 2012; Vernon, 2015; Chan et al., 2021b). The harvesting and consumption of fish in many communities acts as a means of food security, cultural and spiritual practice, and economic prosperity (Hoover, 2013; McAuley & Knopper, 2011; Vernon 2015; Islam & Berkes, 2016). While fish consumption is common in communities, it is often accompanied by a concern related to levels of mercury (Hg) in fish muscle tissue.

Mercury is a common element found throughout the environment where in its inorganic form, it is relatively harmless to organisms. However, when found in its common organic state - methylmercury (MeHg), it can bioaccumulate in organisms and biomagnifies in ecosystems (Lavoie et al., 2013). Methylmercury is known to be toxic and can be harmful to the nervous and immune systems and potentially cause damage to the kidneys and liver. It is especially dangerous to young children and women of childbearing age as it negatively affects neurological development (Health Canada, 2008; Driscoll et al., 2013; Calder et al., 2016; Sunderland et al., 2018). Many factors can influence the levels of methylmercury in fish, including natural environmental conditions, atmospheric deposition, watershed disturbances and resource development (Kelly et al., 2006; Driscoll et al., 2013; Visha et al., 2018). Throughout Canada, fish consumption advisories are posted to manage the risk of eating fish caught in lakes and rivers. This is often done in response to industrial and resource development projects (OMECP, 2023). These projects may threaten sport fish consumption or Indigenous communities' ways of life by making it unsafe to harvest and consume traditional food sources. Common causes of elevated methylmercury exposure often include (but are not limited to) eating fish found in reservoirs or water bodies associated with diversions for hydroelectric development or mining (Heyes et al., 2000; et al., 2004; Kasper et al., 2014; Ponton et al., 2021).

Many such development projects currently exist and are proposed in the Lake Nipigon Basin. A country foods study found that BZA and other Indigenous communities located on the shores of the Lake rely on piscivorous fishes as their primary source of traditional country food (CanNorth, 2016). Walleye (*Sander vitreus*), followed by Lake Whitefish (Coregonus clupeaformis) and Lake Trout (Salvelinus namaycush) tend to be the most caught and consumed fish in BZA and other Indigenous communities across Lake Nipigon and Ontario (CanNorth, 2016; Chan et al., 2021b). With major hydroelectric development and mining exploration around the lake's basin, BZA harvesters have long held concerns about the levels of mercury in fish that they consume.

The Ogoki Diversion of 1943 diverted the Ogoki watershed from flowing north to James Bay through the Arctic watershed down into Lake Nipigon through the Little Jackfish River and into the St Lawrence watershed. This massive diversion of water increased Lake Nipigon's watershed size by over 60% (Figure 1.1). Of note are the series of dams that created the Ogoki Diversion to the northeast and the extensive watershed that was diverted down into Lake Nipigon. It's also worth noting that community members have shared concerns of the impacts from the extensive mining belt just north of the community and the dams on the Namewaminikan and Nipigon Rivers and their impacts on fish contaminant levels.

Large erosional events were observed by fishermen and elders from around the lake including in Ombabika Bay, the entry point for the Little Jackfish River into Lake Nipigon, was inundated with large plumes of sediment after the Ogoki Diversion. This diversion project is known to have altered life on Lake Nipigon by causing major changes to fish populations (Wilson & Haxton, 2021) and altering water levels, forcing community members to relocate from traditional coastal locations (Driben, 1989). Community members have concerns regarding the Ogoki Diversion and the three dams on the Nipigon River below Lake Nipigon and their associated impacts on fish populations and contaminants. Some community members have reported that it is possible to taste the mercury in fish caught from the Little Jackfish River as it is widely known that development projects of this type and scale can drastically increase the availability of MeHg in aquatic systems. With further hydroelectric development proposed for the Little Jackfish River (Ontario Hydro, 2023) mercury levels in fish remain a critical concern for both community subsistence fishing and commercial fishing (Hoover, 2013).

Programs such as the Ontario Ministry of Environment, Conservation and Parks'(OMECP) Guide to Eating Fish provide a broad level of contaminant data for managing the risks associated with consuming and providing fish to the community. However, the current provincial advisories seen in Figure 1.2 created by the Ministry of Natural Resources and Forestry monitoring data do not provide a comprehensive or recent spatial or temporal dataset for the lake. Furthermore, risk communication between BZA and the OMECP regarding contaminant levels is not effective and consumption advisories serve as a colonial exertion of government management over communities and the traditional territory (McAuley & Knopper, 2011; Hoover, 2013).

1.2 Purpose and Objectives

The purpose of this study is to provide a level of confidence and understanding in the risks associated with the consumption of Walleye for BZA. By collecting up to date, spatially explicit fish contaminant data through traditional methods and producing associated consumption guidelines, the community is expected to have a greater sense of food security in continuing to exercise their right to consume traditional foods. We also sought to build capacity in the community by bridging the gaps between traditional western science techniques for risk management and community-based practices of consuming fish.

Objectives of the study include:

i) Produce Fish consumption guidelines for river locations of concern to BZA.

ii) Produce Fish consumption guidelines for lake locations traditionally used by the community.

iii) Compare fish consumption guidelines produced by BZA to those posted by the OMECP.

Using traditional methods to achieve the objectives and produce community-based fish consumption guidelines better allowed community members to understand and communicate the risks associated with eating fish from their traditional territory. Community fishermen captured fish from traditional fishing locations throughout the lake and provided the researcher with fish tissue samples to be analyzed for mercury at Lakehead University's Environmental Laboratory. The sampling provides a robust lake wide dataset over multiple years and includes riverine sampling where hydroelectric dams are present and are of particular concern to the community. This relevant spatial and temporal fish contaminant data for Lake Nipigon provides the community with more confidence in since they've had been a part of the process from the very start, rather than guidelines being dictated by the Provincial Government where there is little trust.

Consumption guidelines produced from BZA sampling procedures were often less restrictive compared to those posted by the OMECP. Fish in river systems also appeared to have higher mercury concentrations, and thus, more restrictive consumption guidelines compared to lake sampling locations. This is likely due to the greater influence of landscape features in river systems. The Namewaminikan River, which is impacted by multiple hydroelectric dams, produced very few Walleye during comprehensive sampling efforts. In the limited sample sizes for fish and data from previous studies, this river system exhibited elevated levels of Hg in both White Sucker (*Catostomus commersonii*) and in the few Walleye caught in its oldest and lowest reservoir. Through a continuous and spatial investigation of community country foods consumption and the potential risks of mercury bioaccumulation, community-based risk management can ensure that those who bare the risk are closely involved in understanding and managing that risk.

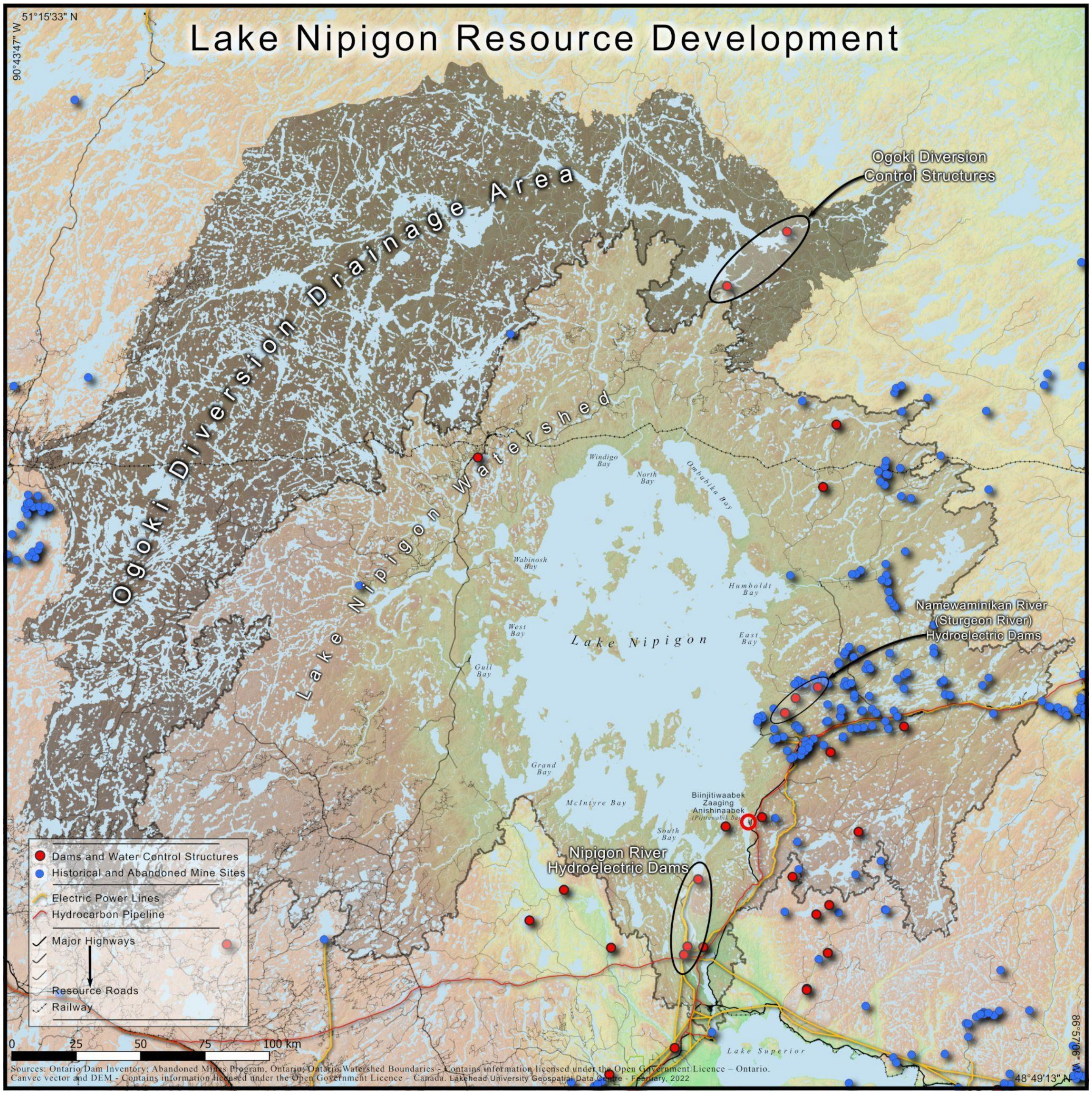

Figure 1.1: Known resource development locations around the Lake Nipigon basin. BZA Rocky Bay is shown at the southeast corner of the lake.

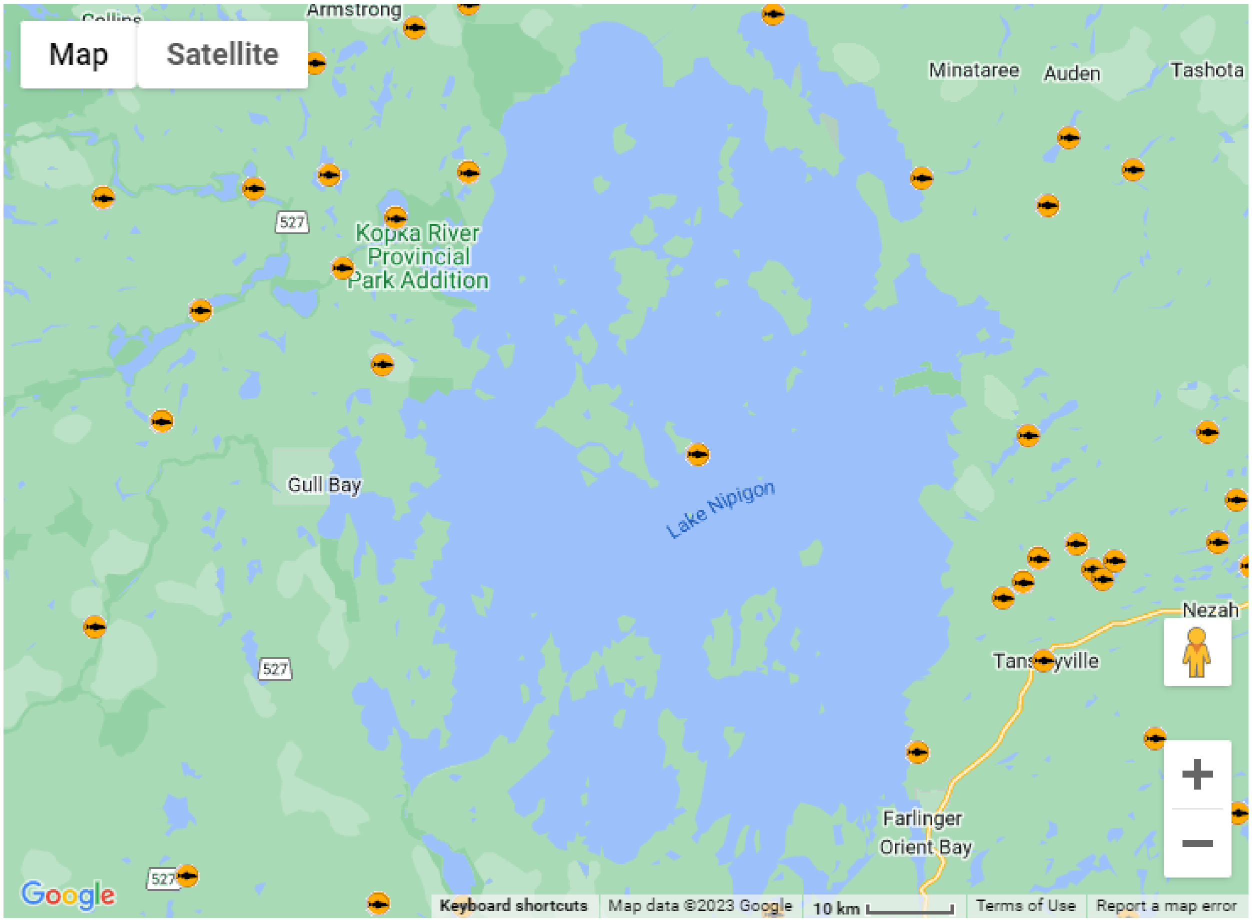

Figure 1.2: Map of Lake Nipigon Guide to Eating Fish (2023) produced by MNRF Broadscale Monitoring and OMECP fish consumption guidelines. Fish icons indicate locations where fish consumption guidelines exist.

Chapter 2: Literature Review

2.1 Methylmercury bioaccumulation in aquatic ecosystems

Inorganic mercury (Hg) is a naturally occurring metal found throughout the aquatic environment and in it's elemental form is relatively harmless to the biotic world. However, when found in its organic form, often methylmercury, it can increase in concentration in organisms over prolonged periods of time which is referred to as bioaccumulation (Lavoie et al., 2013; Rice et al., 2014; Health Canada, 2019). Bioaccumulation can cause elevated levels of mercury in fish, especially in piscivorous fish such as Northern Pike (*Esox lucious*) and Walleye (*Sander vitreous*) (Mathers and Johansen, 1985). Methylmercury rapidly diffuses as it binds to proteins which leads to bioaccumulation in muscle tissue of fish commonly consumed by people (Health Canada, 2008; Lavoie et al., 2013). Fish that occupy higher trophic levels are more prone to biomagnification since organic chemicals move through lower trophic levels of prey species and magnify via ingestion from organism to organism (Hall et al., 1997). Biomagnification is common in aquatic systems since fish methylmercury absorption in muscle tissue happens predominantly through ingestion of prey rather than passive accumulation by way of water passing through their gills (Hall et al., 1997). Typically, it is noted that >90% of total mercury in fish tissue is methylmercury, however proportion can vary widely depending on the surrounding environment and prey type consumed by fishes (Grieb et al., 1990). Bioaccumulation also influences the positive relationship between fish length and mercury concentration (Gewurtz et al., 2011). As fish in higher trophic levels grow in length while consuming prey fish, their concentrations of total mercury also increase. This process allows for a calculation of average fish mercury concentrations at standardized lengths for a given population or community (Gewurtz et al., 2011).

2.2 Influences on methylmercury concentrations in fish

A number of factors can influence the concentration of mercury and the rate of methylation in the environment, which ultimately affects MeHg in fish. The process of methylation is mostly driven by anaerobic microbial activity in sediments, peatlands and hypolimnetic waters (Eckley et al., 2017). Other factors that positively affect methylation in freshwater aquatic ecosystems include dissolved organic carbon (DOC) found in the water, anoxic conditions, pH, sulfate and iron reducing bacteria influence mercury activity in the aquatic environment and promote methylation (Gilmour et al., 1992, Driscoll et al., 1995; Hsu-Kim et al., 2013; Gilmour et al., 2013).

Environments with high rates of decomposition, such as inundated soils or vegetation, are known to contribute to elevated levels of methylmercury (Driscoll et al., 1995; Driscoll 2013). The creation of head ponds and impounds that submerge soils and vegetation, or the increased flow in river systems that cause bank erosion, can cause elevated levels of mercury within aquatic systems piscivorous fishes (Kasper et al. 2014; Silverthorn et al., 2017). Such phenomena are common when constructing dams or diversion projects for hydroelectric or navigation purposes (Bodaly et al., 1984). The amount of mercury that is made bioavailable after the flooding of an impounded area is very closely related to the type of soil and amount of vegetation that is flooded. Specifically, the amount of carbon found in the landscape along with sulfate reducing bacteria tend to be the greatest indicators of the amount of mercury methylation of a flooded landscape (Driscoll et al., 1995; Heyes et al., 2000; Gilmour et al., 2013; Calder et al., 2016). This is primarily due to the binding of mercury to DOC in the water thereby allowing it to be more active in the environment (Driscoll et al., 1995; Lavoie et al., 2019). The type of dam constructed also has an impact on how much mercury is made active and bioavailable (Poff & Hart, 2002). For example, the mercury levels associated with 'run-of-river' dams may not be considered as great of a concern due to the relatively small, flooded area and reduced erosion compared to an 'impoundment' dam which can flood a much greater area. However, multiple 'run-of-river' dams on a river system can increase landscape submersion and erosion from a cumulative effects perspective.

Extensive research both in natural environments and in experimental settings have examined the mechanisms and time course of elevated Hg levels at various trophic levels within flooded environments. Due to the negative health impacts associated with consuming fish, much of the emphasis of previous studies has been placed on understanding MeHg in higher trophic levels and piscivorous fish species which may pose a greater risk to human consumption. Walleye are often referred to as being the greatest risk for human consumption due to their relatively slow growth rates relative to their high trophic levels and common human consumption (Health Canada, 2008; Lavigne et al., 2011). Typically, in impounded ecosystems Walleye Hg concentrations reach peak levels between 3- and 7-years post impoundment, followed by a very gradual decline in fish tissue Hg levels (Bodaly et al., 2007). These increased concentrations are known to persist for more than two decades, though in some cases may not decrease depending on management of flows (Mailman et al., 2006).

2.3 Run-of-River Dam development

The growing trend to produce renewable energy has put a greater focus on the need to develop hydroelectric power. Canada's vast number of lakes and rivers, offer great potential for the production of such power. With the emergence of run-of-river dams in producing hydroelectric power, communities are presented with an option that requires less capital investment and less environmental impact than traditional, large scale impoundment dams (Anderson et al., 2015). Run-of-river dams are loosely defined across disciplines but are typically considered dams with no stratified impound, or where the water level upstream of the structure does not exceed the natural bank-full height (Poff et al., 2002; Anderson et al., 2015). Though they are broadly considered to be less harmful to the environment than traditional impoundments, much is still unknown about how run-of-river dams influence their river systems (Anderson et al., 2015). While the impact *may* be less severe than impoundment dams, run-of-river structures can impact a variety of river ecosystem features.

Run-of-river dams have been found to produce stratification of deep pools further upstream and in back flood tributaries, causing changes in water residence times, biochemical oxygen demand, partial pressure of CO_2 and organic carbon (Silverthorn et al., 2017; Ponton et al., 2021). These are all features shared with the implementation of impoundment or "storage" dams (Almeida et al. 2019). Run-of-river structures are also known to have negative impacts on stream fish and macroinvertebrate communities by fragmenting river landscapes, which degrades habitat and water quality (Santucci et al., 2004). These structures also induce fine sediment deposition, trapping metals, other contaminants and organic matter (Anderson et al., 2015; Ferriz et al., 2021), while also reducing bedload carried downstream which can reduce channel diversity and degrade habitat for spawning fishes (Anderson et al., 2015; Ferriz et al., 2021). The deposition of Hg and organic matter seen in head ponds and impounds can contribute to increased methylation rates within run-of-river and larger reservoirs can lead to further bioaccumulation and biomagnification, especially in systems that may be facing disturbance from forest fires and logging (Ferriz et al., 2021). Currently these smaller structures are not often assessed cumulatively, and numerous dams can be located on one river system with individual permits to take water within the province of Ontario. This can allow for an increase in the head pond size from the originally proposed and approved plan and cascading cumulative effects. Given that head ponds and impounds can export mercury and methylmercury to downstream environments (Kasper et al., 2014; Silverthorn et al., 2017), there is a risk associated with multiple successive structures on a river system, as seen on the Namewaminikan River (Anderson et al., 2015; Silverthorn et al., 2017; Ponton et al., 2021).

2.4 Mercury Contamination and First Nations Water Resources

Indigenous and minority populations are often exposed to environmental pollutants and contaminants at much higher rates than the general population (Derrick et al., 2008). Many examples of this environmental racism exist around the world and in Canada. Indigenous communities are also much more vulnerable to the effects of environmental pollution compared to the general population due to their deep and intimate connection with the land (Dellinger, 2004; Chess et al., 2005; Derrick et al., 2008; Brunet et al., 2020).

While there are many contaminants that have been found to impact Indigenous and First Nations people in Canada, one of the most common and devastating contaminants associated with watersheds has been methylmercury (Chan & Receveur, 2000; Health Canada, 2008). The James Bay hydroelectric project is one of the most famous cases of hydro dam reservoirs increasing mercury bioaccumulation and biomagnification in fish that impacted the physical health of the Cree of Northern Quebec (Berkes & Farkas, 1978; Moriarity et al., 2004; Ripley et al., 2018). Impacts to the Cree were so severe that a moratorium on eating fish was ordered and the Cree were resettled into reserves away from their native lands (Ripley et al., 2018). The contamination of fish was caused by the impounds of the dams and associated cumulative effects of the vast engineering structures within the watershed (Ripley et al., 2018). This instance was particularly devastating due to the flooding of carbon rich soils of the region, which is known to exacerbate methylmercury bioavailability in aquatic ecosystems (Mailman, 2006; Ponton et al., 2021).

In northern Ontario the impacts of mercury bioaccumulation on Indigenous Peoples' health was also experienced from years of mercury being dumped into the English Wabigoon river system, contaminating aquatic food chains (Ilyniak, 2014**)**. This regulated release of mercury into the English Wabigoon River was so severe that mercury bioaccumulation in the fish caused minamata disorder among community members. This risk still exists today and represents a dark colonial history of environmental injustice for Indigenous Peoples in Canada (Ilyniak, 2014).

The scale and severity of impacts in these examples were not well understood until many years after these communities were affected by high concentrations of mercury in the food chain. Furthermore, community members are not often included in the monitoring activities, meaning there is little early warning of a health risk related to eating impacted fish populations. The lack of involvement in monitoring and advisory processes leaves communities with feelings of fear and a lack of trust for governments that manage the risk using expertise and bureaucracies that have poor risk communication strategies historically and fail to interpret the risks from a community-perspective (McAuley and Knopper, 2011).

2.5 Fish Consumption Advisories

Fish consumption guidelines are often produced to manage the risk associated with consuming fish that contain contaminants from areas impacted by resource development, atmospheric deposition or where fish mercury levels are naturally higher (Gewurtz et al., 2011;

OMECP, 2013). Fish consumption guidelines are a risk management tool used by governments to restrict the consumption of certain species/size of fish, or to educate and provide guidance to citizens on how to avoid consuming high levels of contaminants, such as mercury (Gewurtz et al., 2011). The intention is to standardize fish mercury levels or contaminants of concern at a given length for specific populations of fish. The guidelines or restrictions then tell consumers how many meals per month they can likely eat without experiencing any adverse health effects. One meal is considered to be 8oz or 227g of fish, or about the size of the average person's palm including their fingers (OMECP, 2023). Generally, these advisories are developed using a sample size of at least ten individuals from across as wide a range of sizes as are encountered during sampling to accurately provide a representation of the fish present in a given waterbody or area (OMECP, 2023). Due to the toxic nature of mercury in the human body, guidelines are developed for the general population and a sensitive population which includes women of childbearing age and children under 15 years of age.

It is well documented that fish consumption advisories often fail to serve their intended purpose and lack the robust communication and risk management to guide diverse groups of resource consumers (Chess et al., 2005). Indigenous communities are especially overlooked when it comes to the implementation and utilization of fish consumption advisories as their habits of consuming fish tend to differ greatly from the rest of the population (Chess et al., 2005; US EPA, 2023;). On average Indigenous communities and peoples across the US eat 3 to 30 times the wild fish compared to the rest of the population (US EPA, 2023) placing them at greater risk of being affected by environmental contaminants in fish. It has also been shown that lower income and ethnic groups across North America are much more likely to eat fish that they catch from sport fishing as it is a valuable and cost-effective source of protein (Burger et al., 1999). Health Canada (2008) published a review of studies that examined fish consumption rates across the general population and in First Nations communities. This review found that recreational or subsistence fishers in Canada range from 9.0 g/day (Kostasky et al.1999) up to 87 g/day (Loranger et al. 2002). In First Nations and Inuit communities' consumption also ranged drastically between 14 g/day (Richardson and Currie, 1993) and 131 g/day (Dewailly et al. 2003) and the average was approximately 38g/day or 5 fish meals per month using the OMOECP standard of a 227g meal. It should be noted that many of these studies were conducted for different reasons and through different techniques, and results should be used cautiously when comparing amongst groups.

In BZA the community consumes more fish than any other Indigenous community on Lake Nipigon. This estimate is based on the average of 86.9g/pp/day as calculated by the 2016 CanNorth Country Foods study that surveyed and interviewed community members from around Lake Nipigon (including 14 female participants and 16 male participants from BZA) to understand country food consumption rates and community concerns. This consumption of fish per day translates to about 11.5 meals per month of fish based on the OMECP's average meal of 227g. This fish consumption intake is drastically higher than the average population estimate from The Bureau of Chemical Safety, Food Directorate of 22g/day to represent the finfish consumption for commercial consumers and 40g/day to represent the finfish consumption for sportfish or subsistence consumers (Health Canada, 2008).

The lack of context and communication associated with consumption advisories renders them difficult to apply and use on a regular basis for populations who regularly harvest wild fish for subsistence purposes. Since Indigenous communities rely upon fish as a source of healthy food, cultural practice, and economic prosperity (Lambden et al., 2007; Power, 2008), consumption advisories are often overlooked due to their lack of cultural awareness and effective communication. This tends to create conceptions of fear, confusion or mistrust in communities affected by fish consumption advisories (Burger et al., 1999; Chess et al., 2005). These issues stem from the creation of fish consumption advisories that were developed as a restriction for sport fishing when mercury levels were detected to be potentially dangerous to the population.

Called “Sport Fish Consumption Restrictions” in Ontario, the province enacted restrictions when high levels of contaminants were expected in areas associated with high atmospheric deposition or industrial activity. The restrictions were intended to address sport fishing as this community of users could simply stop eating certain fish and follow the restrictions within the ‘sport’ of fishing. The restrictions were not developed for commercial or subsistence fishing communities. In recent years the Fish Consumption Restrictions for Sport Fishing have been renamed the “Fish Consumption Guidelines” to better reflect a more educational and holistic risk management approach for citizens to avoid contaminants of concern through personal behaviour and placing responsibility on the user.

The reality for many communities, however, is to overlook fish consumption advisories when they are introduced and continue to eat the fish regardless of the monitoring updates or changes to the guidelines. Consequently, paying little attention to the guidelines, or listing a fish as contaminated, can eventually lead to fear about eating the fish and people cease to harvest and eat fish from traditional fishing locations affected by industry and consumption advisories (Berkes & Farkas, 1978; Dellinger, 2004; Hoover, 2013; McAuley & Knopper, 2011).

When resource managers and industry fail to effectively communicate consumption restrictions or guidelines to communities it threatens their food security and cultural ways of life. For example, the Guide to Eating Fish in Ontario advises consumers to trim the flesh from around the belly of the fish or to avoid eating fish organs in general (OMECP, 2023). This guidance is intended for users to avoid eating areas of fish that may have more fatty tissue where organic contaminants may build up, or in organs that may filter contaminants. This guidance therefore restricts eating parts of the fish that are key to traditional practices where consumers utilize as many aspects of the fish as possible.

Another example from a survey of Indigenous people living on Lake Nipigon found that 65.3% of respondents had concerns over Walleye contaminant levels and the safety of consuming fish (CanNorth, 2016) with 50% of those interviewed indicated they were very or extremely concerned about the consumption of Walleye from rivers and shorelines affected by recent development. Respondents cited hydroelectric dams, metals from abandoned mines and runoff from aerial herbicide spraying as key sources of concern for contaminants in the fish they are eating (CanNorth, 2016). These trends associated with traditional fish consumption have created a need for community-based consumption advisories (Dellinger, 2004; Derrick et al., 2008; Brunet et al., 2020; Poirier, 2023). In order to ensure trust and use of guidelines in community practices, it's important that resource users are aware of the methods and procedures used to derive these guidelines (Song et al., 2013).

2.6 Indigenous Community-Based Monitoring

With land-based foods being essential to culture and health in communities, the security and sustainability of these food sources is extremely important to the communities that rely on them. Land based foods help Indigenous community members connect and engage with the land while also being very high in nutritional value and providing food security (Gagné et al., 2012; Seabert et al., 2014; Vernon, 2015; Islam & Berkes, 2016). One way to promote the sovereignty and protection of these land-based foods for community health and security includes community engaged and coordinated research, whereby community members lead and conduct research to answer critical questions related to their traditional lands and foods as well as the risks associated with development on their traditional lands (Reed et al., 2020; Poirier & Neufeld, 2023). The forced changes to landscapes and food sources from colonial pressures have meant that in many ways, Indigenous communities were disconnected from their traditional food sources. This disconnect has impacted the physical, cultural, spiritual and emotional well-being of First Nations (Hoover, 2013; McAuley & Knopper, 2011).

Community based monitoring has the ability to greatly enhance a community's capacity to understand and deal with changes and potential threats to their natural resources (Raygorodetsky & Chetkiewicz, 2017; s et al., 2017). Specifically, First Nations within Canada are well positioned to incorporate community-based monitoring and risk management in their land management practices. The long-standing communication of traditional ecological knowledge within communities provides the opportunity to incorporate traditional practices and knowledge into the management of their natural resources in a way that provides participation and meaningful dialogue within the community (Stephenson et al., 2014; Brunet et al., 2020). While incorporating TEK and local knowledge into western land management practices can be difficult, there are multiple examples from arcross the country that demonstrate that it is possible (Raygorodetsky & Chetkiewicz, 2017; Brunet et al., 2020). Methods such as interviews or local knowledge collection from hunter gatherers, combined with tools commonly used in science (i.e., GIS applications), can provide valuable techniques and insights into more culturally appropriate land use practices that are important to local communities (Moller et al, 2004; McCarthy et al., 2012; Aggrey & Godfrey, 2018). Furthermore, the incorporation of these community practices can offer a way to improve social and cultural landscapes within communities as First Nations culture is deeply connected to the natural environment.

This deep connection that communities have with their surrounding environment places them in an ideal position to monitor changes in the landscape and communicate them in a way that provides meaning for their community and insight to western systems (Stephenson et al, 2014). When First Nations are at the forefront of monitoring and risk-based decision-making on their lands, they can increase sovereignty in resource management and allow for community interests to benefit, and when conducted in meaningful and respectful dialog and engagement among all parties, has the potential to also benefit government and private industry interests. Community based monitoring programs such as the Indigenous Guardians program provide communities like BZA the opportunity to explore and understand risks or concerns firsthand and increase their self-determination by managing these risks themselves (Reed et al., 2020).

Chapter 3: Case Study

3.1 BZA Lake Nipigon

Hydroelectric development has played a large part in the history of Lake Nipigon. While there are no settler communities on the shores of Lake Nipigon, the four Indigenous communities on the lake's shore have observed and felt the impacts of these large-scale projects. There are several large-scale hydroelectric development projects around the Lake and its tributaries, including multiple large dams on the Nipigon River (the lake's main outflow into Lake Superior) and the Ogoki diversion, and more recently a series of dams on the Namewaminikan River with proposed development on the Little Jackfish River. Hydroelectric development remains a viable and profitable course for economic development, especially in the case of run-of-river hydro dams which often require less initial capital, and reduced environmental assessments, carrying less overall associated risk compared to traditional, large-scale impoundment or "storage" hydroelectric projects (Buckland & O'Gorman, 2016). With many first nations communities relying on the lake and its surrounding resources (CanNorth, 2016), it's crucial that the impacts of these structures and the status of fish contaminants are well-known and well-understood by community fishermen and resource users.

BZA has long depended on the harvesting of Walleye and other fish from Lake Nipigon for commercial, cultural and subsistence purposes and continues to regularly harvest and consume these fish more than any other country food (Figure 3.1). Community members often share concerns over the risk of eating fish from specific locations around the lake such as Ombabika Bay, the Little Jackfish River and the Namewaminikan River. Popular fishing locations like McIntyre Bay, Humboldt Bay and Wabinosh Bay are also important as they are more accessible for community members on the lake (Figure 3.2).

Community concerns stem primarily from the increase in Hydroelectric and resource development in the watersheds of popular fishing locations listed above. The community and its fishermen have long observed changes to the Lake Nipigon fishery and have investigated them through the Rocky Bay Fisheries Unit (est. 1993) and with partners at the Aboriginal/Ontario Fisheries Research Center (AOFRC). The Rocky Bay Fisheries Unit was created to understand the impacts of hydroelectric development on lake fish populations using both traditional knowledge and western science data collection techniques. By studying fish populations and their associated threats, the Fisheries Unit sought to increase their understanding, authority, and responsibility for the waters, thereby creating an economic basis for development and self-sufficiency. The Unit's studies focused on fish populations and movement across the lake, working collaboratively with the Ministry of Natural Resources and Forestry and the AOFRC to capture, tag and recapture Walleye, Lake Sturgeon and Northern Pike.

With investment in two new dams on the Namewaminikan River in 2017, community concerns arose over the levels of methylmercury in fish due to the associated flooding of soils. The development of the High Falls dam on the Namewaminikan River, a sacred site to many Indigenous peoples in the region, was largely opposed by community members in 1995 when the dam was first constructed. Fish consumption restrictions were implemented shortly after construction as fish mercury levels were found to be high (Awad, 2010) with causes likely attributed to logging, mining and the reservoir created on the river. In 2017, two new run-of-river dams were built upstream of the High Falls reservoir in partnership with multiple Indigenous communities around Lake Nipigon. Shortly after the dam was constructed, a 50% increase in head pond size was proposed by the hydro company. These changes again raised community concerns over mercury levels in fish within the Namewaminikan River as the dams risked flooding more land than proposed which could result in impacts that resemble the more traditional impoundment or storage dams of the past. In addition to these changes, both provincial Fish Consumption Guidelines and a previous study with BZA (Wilson and Stewart, 2017) identified mercury as the most concerning contaminant in the tissue of fish samples impacting country foods for local Indigenous communities.

As opportunities arise to continue along the path of development on other river systems, BZA-Rocky Bay identified a need to develop an understanding of the ecosystem impacts of hydroelectric development in watersheds that have historically been exploited. By implementing a methodology centered on community fishing perspectives and practices, BZA has created a formidable and robust fish mercury database, with community commercial fishermen as guiding hands in data collection. With community fishermen at the center of data collection, the community has become more invested in environmental research and monitoring.

Average daily intake of country foods by type and community based on Food Frequency Questionnaire results, 2015.

Country Food Type	**Average Daily Intake (g) - Per Community**				
	AZA	**BNA**	**BZA**	**KZA**	**Total**
Fish	**27.3**	**38.0**	**86.9**	**71.0**	52.4
Birds	8.6	5.2	7.5	18.2	8.9
Mammals	21.6	17.2	30.1	55.6	27.5
Edible plants	11.3	13.4	19.0	26.2	15.8
Total	68.8	73.9	143.5	171.1	104.6

Bolded entries indicate the top country foods type at each community.

Figure 3.1: Average daily intake of country foods per community from the CanNorth 2016 Country Foods Study.

3.2 Study Area

Lake Nipigon (Animbiigoo-zaagi'igan) is a large lake (4,848 km^2) often referred to as the mother of the Great Lakes since it is the largest tributary to Lake Superior. Lake Nipigon drains a vast area originally of 24, 560km^2, now 38, 920km^2 due to the Ogoki Diversion of 1943 which accounts for a 63% increase in watershed size. It is the home of the Ojibway, including multiple Indigenous communities such as Animbiigoo Zaagi'igan Anishinaabek First Nation (Lake Nipigon Ojibway), Bingwi Neyaashi Anishinaabek (Sand Point First Nation), Kiashke Zaaging Anishinaabek (Gull Bay First Nation), Whitesand First Nation and Biinjitiwaabik Zaaging Anishinaabek (BZA - Rocky Bay First Nation). The Ogoki Diversion enters Lake Nipigon via the Little Jackfish River, which flows into Ombabika Bay at the north end of the lake.

Ombabika and Humboldt Bay

Ombabika Bay is known to be a major source and spawning ground for the greater Walleye population of Lake Nipigon with the Little Jackfish and Ombabika Rivers acting as productive spawning rivers (Rocky Bay Fisheries Unit, 2005). The Bay is ~30km long and ~5km wide with a very narrow mouth to the open lake which creates the illusion of a separate lake at the north end of Lake Nipigon. The bay is much different from the rest of Lake Nipigon both physically and biologically, with water containing much higher DOC and lower water clarity compared to the main lake. The Ombabika Bay piscivorous fish community is dominated by Walleye and Northern Pike, generally lacking Lake Trout and Brook Trout populations that are often abundant across the rest of the Lake. The neighbouring Humboldt Bay is also a well-known source of Walleye populations with the Onaman River serving as a reliable spawning ground for Walleye. Wabinosh, Chief’s and McIntyre Bays are the other main sources of Walleye spawning on the lake according to commercial fishermen and community elders. Studies conducted by the Rocky Bay Fisheries Unit also support these claims.

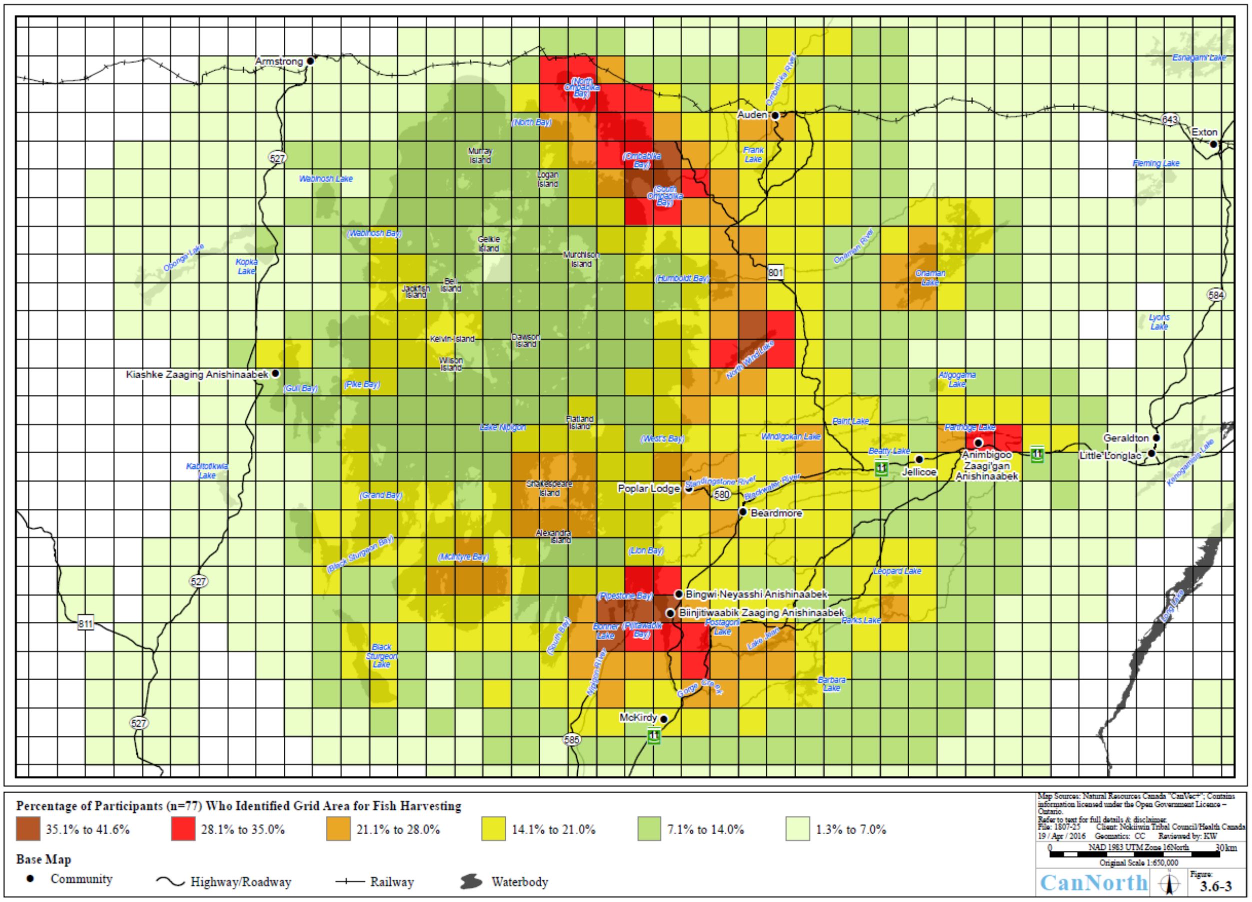

Figure 3.2: Map depicting traditional fishing locations indicated by 77 Nokiiwin Tribal Council members from survey results during the 2016 CanNorth Country Food study.

Chapter 4: Methods

4.1 Community Input and Consultation

In 2019 BZA contacted Lakehead University as there was a proposed increase of head pond size by 50% to the two new dams on the Namewaminikan River (Twin Falls and Long Rapids, est. 2017). The Community also shared concerns over the lasting impacts of the Ogoki Diversion.

Throughout 2019, Lakehead University met with the Community Chief and Council, and employees from the BZA Lands and Resources Department to discuss areas of concern to the community and to devise a study that would help grow BZA's capacity to conduct research and monitoring and develop a database for fish contaminants in the Lake Nipigon Basin. Community Band Council members including elders and commercial fishermen were also involved in initial study planning. While the pressing issue of an increased headpond size on the Namewaminikan River was the original concern of BZA. Discussions grew to include concerns about the history of hydroelectric development on the larger Lake and the potential fish contamination that may exist in a variety of traditional fishing locations.

In these sessions, the community expressed their concern over specific areas of Lake Nipigon, including Ombabika Bay, Humboldt Bay, MacIntyre Bay, Chief's Bay, Gull Bay, Wabinosh Bay as well as the Little Jackfish, Ombabika and Namewaminikan Rivers. These were all identified as areas traditionally used by families for the harvesting of fish and other animals historically (Figure 3.2) where observed impacts from development were noted. The most notable concerns regarding Hg contamination of fish in Ombabika Bay and the Little Jackfish River were due to the Ogoki Diversion's legacy and continued impacts of erosion on the

Little Jackfish River (Figure 4.1). The potential contamination of fish in the Namewaminikan River and the associated impacts of the three dams on the river were also a key concern of the community.

4.2 Fish Data Collection

Fish sampling locations were determined by commercial fishermen in the community, elders and support from the AOFRC. Net set location, duration and collection was led by commercial fishermen. Once nets were pulled community fishermen removed fish from the nets which were then sorted by species. Sampling of dead fish was conducted by myself and biologists from the AOFRC while training and support was provided to community fishermen and members about sample procedures required to support mercury analysis.

Fish were collected using gill nets with single panels approximately 10m long and 2m high, with a mesh size of 5.08cm to 12.7cm. Fish sampling effort focused primarily on retrieving Walleye, as they are of particular concern to the community (CanNorth2016), and serve as good indicators of environmental mercury levels due to their high trophic level and piscivorous diet. White Sucker were sampled on the Namewaminikan River since they were the only fish caught in sufficient numbers at this location. A variety of other species caught as bycatch in sampling efforts including Northern Pike and Lake Whitefish were also sampled.

Net set duration was guided by commercial fishermen with the hope that only enough fish to produce consumption guidelines would be met. Typically, nets were set for approximately 12 hours. Once nets were pulled, the community fishermen would remove the fish from the nets and sort them for sampling.

Twenty to thirty fish samples were sought at each site location to provide a representative distribution of fish sizes and ages from both small and large mesh sizes. Fish sampling was conducted in the Namewaminikan River system within each of the three reservoirs (High Falls, Long Rapids, Twin Falls) located on the river (Figure 1).

Fish were also sampled from the Little Jackfish and Ombabika Rivers by way of angling after it was determined it was not safe to set nets in these rivers due to high densities of coarse woody debris and high flows preventing the safe deployment and retrieval of nets, along with the high efficacy of angling for Walleye in these rivers. Fish sampling in Lake Nipigon took place at traditional fishing locations in the 5 different bays that included Ombabika Bay, Humboldt Bay, MacIntyre Bay, Gull Bay, and Wabinosh Bay.

Fish sampling included measuring fish length (total and fork), weight, species ID, visual inspection of general fish health and a one-inch by one-inch muscle sample which was taken directly behind the dorsal fin, down to the lateral line. Muscle samples were placed on ice in the boat's chest freezer and immediately frozen upon return to land. When accompanied by biologists from the AOFRC, fish were sexed and age structures were taken to estimate fish age.

In total four, separate week-long sampling trips were carried out, one in the fall of 2020 along the eastern shore up to Ombabika Bay, one in the early summer of 2021 along the south and west shore, a third trip in the late summer/early fall of 2021 back along the eastern coast with the goal of reaching Windigo Bay in the north, and a fourth trip in August of 2022 to Ombabika Bay and the Jackfish and Ombabika Rivers. Due to limited harbouring locations and some equipment malfunctions, Windigo Bay could not be sampled.

All muscle tissue samples were analyzed by the Lakehead University Environmental Laboratory (LUEL). LUEL is an International Organization for Standardization ISO 17025 accredited Laboratory. Samples were analyzed using methods from the following two EPA methods 1630 and 1621. To ensure accuracy and quality control LUEL calculated the percent difference between two identical samples for the duplicate analysis and test a substance with a known concentration (dried fish tissue) and calculated the percent difference from the expected value. Boundaries were determined through statistical analysis of historical data (3 standard deviations from the mean) based on the "Three sigma rule".

4.3 Statistical Analyses

Statistical analysis followed the procedures recommended by the OMECP fish consumption guidelines in the statistical program R (version 4. 1.2).

Statistical analysis for comparing mercury concentrations at a standardized length for fish collected was based on a fitted linear regression model for both logHg (total Hg) and logLength (total length). This is followed using the power function as used by the OMECP and described in Gewurtz et al., 2011. Using the intercept and strength of relationship between loglength and logHg concentration for each species and sampling location, the power function $HgL=aL^b$ is applied to year-specific data. Here, *HgL i*s the estimated Hg concentration at length *L* (cm), *a* is a constant, and *b* is the power of the relationship between concentration and length from the log transformed model. Fish were then binned by length using 5cm intervals across the range of fish sizes caught at each sampling location.

Estimated mercury values were then calculated for the max value of each bin and used to delineate the meals per month for the general population and sensitive population. The sensitive population refers to those who are pregnant or may become pregnant and children under 15 years (OMECP, 2023). Thresholds for meals per month according to estimated Hg per bin as described by the OMECP are shown in Table 4.1 for the sensitive population and Table 4.2 for the general population (OMECP, 2017).

Sample sizes of at least ten fish per location are used to derive fish consumption guidelines produced by the OMECP. In this study, sample sizes of at least 20 fish were sought at each location to ensure confidence in results and limit variability. As described in in Gewurtz et al., the relationship between of fish Hg and length increases in strength as sample size increases due to the decreasing variability of Hg levels as samples grow. To create conservative guidelines that properly manage risk, fish meals per month values were derived based on estimates of mercury for the highest value per bin. This means that the meals per month for a fish in the size range of 20-25cm is derived based on the estimated value of Hg produced by the power function for a fish at 25cm.

Fish Hg levels were produced for each study location in R and displayed in tables and figures using Microsoft Excel (Version 2349).

Results from BZA's sampling procedure and fish consumption guidelines were compared to the posted OMECP guidelines to view if any difference in consumption guidelines arose due to sampling differences or temporal changes.

Data and results have been shared in the community through technical reports, presentations in the community, sessions of land based learning and fish sampling with youth and knowledge keepers and with community participation at various conferences.

Table 4.1: Estimated Hg thresholds for a given length of fish and the associated number of meals per month for the Sensitive Population (women of childbearing age or children under 15 years of age) according to the OMECP.

Estimated Modelled Hg (ug/g)	Sensitive Population (meals/month)
Hg>0.5	0
0.5≥Hg<0.25	4
0.25≥Hg<0.16	8
0.16≥Hg<0.12	12
0.12≥Hg<0.6	16
0.06<Hg	32

Table 4.2: Estimated Hg thresholds for a given length of fish and the associated number of meals per month for the General Population.

Estimated Modelled Hg (ug/g)	General Population (meals/month)
Hg>1.8	0
1.8≥Hg<1.2	2
1.2≥Hg<0.6	4
0.6≥Hg<0.4	8
0.4≥Hg<0.3	12
0.3≥Hg<0.15	16
0.15>Hg	32

Figure 4.1: Orthomosaic produced via drone imagery of a large bank slide near the mouth of the Jackfish River. Land scars can be observed along the riverbank throughout the river system, likely due to extremely high flows from the Ogoki Diversion.

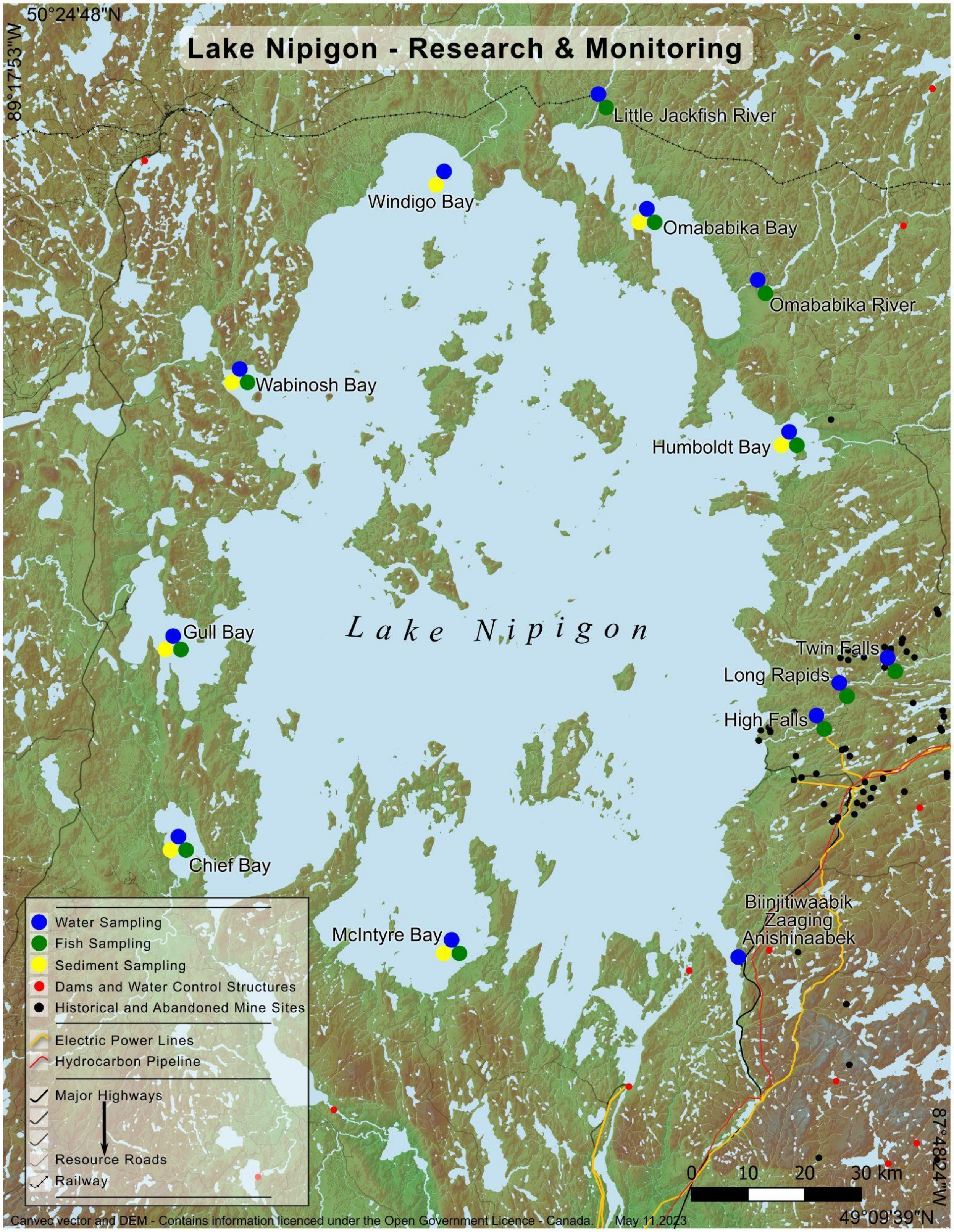

Figure 4.2: Map of fish collection locations around Lake Nipigon.

Chapter 5: Results

5.1 General Results

This chapter provides the results of the fish consumption guidelines produced from the sampling of three river systems (the Namewaminikan River, the Little Jackfish River and the Ombabika River); the fish consumption guidelines produced around Lake Nipigon (from Ombabika Bay, Humboldt Bay, McIntyre Bay and Wabinosh Bay) and; the comparison of the resulting BZA fish consumption guidelines compared to the posted OMECP fish consumption guidelines for Lake Nipigon.

Across all sites, Hg levels had a positive correlation with fish length and sites associated with river environments demonstrated higher levels of Hg in fish (Figure 5.1.1). Across all study sites (except for the Namewaminikan River), fish consumption guidelines produced from BZA sampling were generally less restrictive than those provided in the current OMECP fish consumption guidelines. Specifically this is seen where BZA's consumption guidelines for both Ombabika Bay and the adjoining Little Jackfish River were less restrictive than the OMECP's in all sizes except for the 45-50cm bin in the Little Jackfish River(Figure 5.1.2). Additionally, lake consumption guidelines for Ombabika Bay were less restrictive than the adjoining Little Jackfish River. This is representative of another trend seen throughout the dataset, where lake locations generally had less restrictive consumption guidelines compared to river locations. Since no OMECP consumption guidelines for specific bays exist on lake Nipgion, consumption guidelines produced by BZA in bays of concern were compared to the single guidelines provided by the OMECP for Lake Nipigon, which provides a lake-wide recommendation for managing consumption risk for each species caught at any fishing location on the lake.

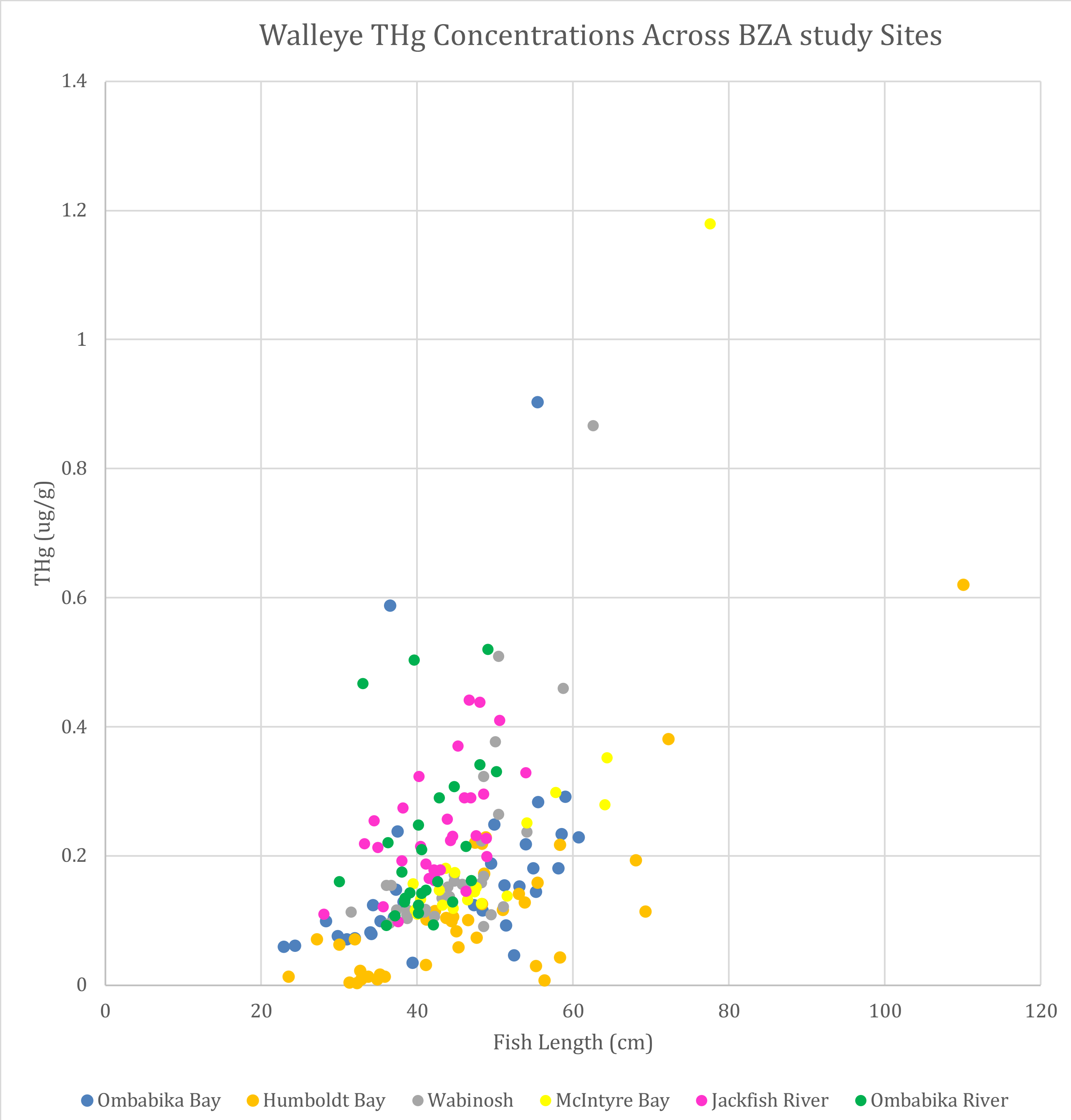

Figure 5.1.1: Walleye total mercury (THg) concentrations for all fish caught across the study except for those caught in the Namewaminikan River, including those caught in the Jackfish and Ombabika Rivers. Fish THg levels typically increase with length across all sites for Walleye.

Figure 5.1.2: Graphs indicating the consumption guidelines produced for the Little Jackfish River produced by the Ontario Ministry of Evnironment Conservation and Parks (OMECP) and fish consumption guidelines produced by BZA for the Little Jackfish River and Ombabika Bay.

5.2 Namewaminikan Consumption Guidelines

In the fall of 2020 nets were set for 24 hours overnight in each of the three headponds, at depths of 3-4m, however, only one whitefish and one northern pike were caught in the Twin Falls and High Falls reservoirs respectively. These fish were not sent for analysis due to their limited sample size. The following summer of August 2021, nets were once again set for 24 hours overnight at three locations (Figure 1) on the Namewaminikan River. The only location where numerous fish were caught was in the High Falls reservoir, the lowest of the three head ponds on the Namewaminikan River (refer to Figure 5.1.1). In total, 24 White Suckers, and three Walleye were caught and sampled.

The Namewaminikan River was one of the few sites throughout all of BZA's sampling that matched or was more restrictive than the OMECP's posted consumption guidelines, specifically for White Sucker (Table 5.2.1).

The High Falls Reservoir exhibited elevated levels of fish Hg when compared to nearby reference locations. Mercury levels for White Sucker in the High Falls reservoir had a mean Hg of 0.64ug/g and a mean length of 50.28cm with 85% of fish caught in the reservoir between both the 2017 and 2021 studies above the Health Canada consumption exceedance value of 0.5ug/g. Previous studies had been successful in catching Walleye within the river system (Figure 5.2.1) which suggested elevated levels of Hg in Walleye within the High Falls Reservoir when compared to other river sample locations. The three Walleye sampled in 2021 fit the same trend of having higher levels of mercury which, when combined with 2017 data had a mean Hg of 0.8ug/g, at a mean length of 43.01cm) compared to downstream sites which had a mean Hg of 1.66ug/g at a mean length of 46.03cm.

Based on the 2016 CanNorth country foods survey which indicated that BZA community members consume 86.9g per day of fish, which translate to roughly 12 meals per month eating any fish from the High Falls reservoir would not be recommended for the sensitive population for Walleye or White Suckers as guidelines for any fish length did not exceed more than 4 meals per month for Walleye and 0 meals per month for White Sucker.

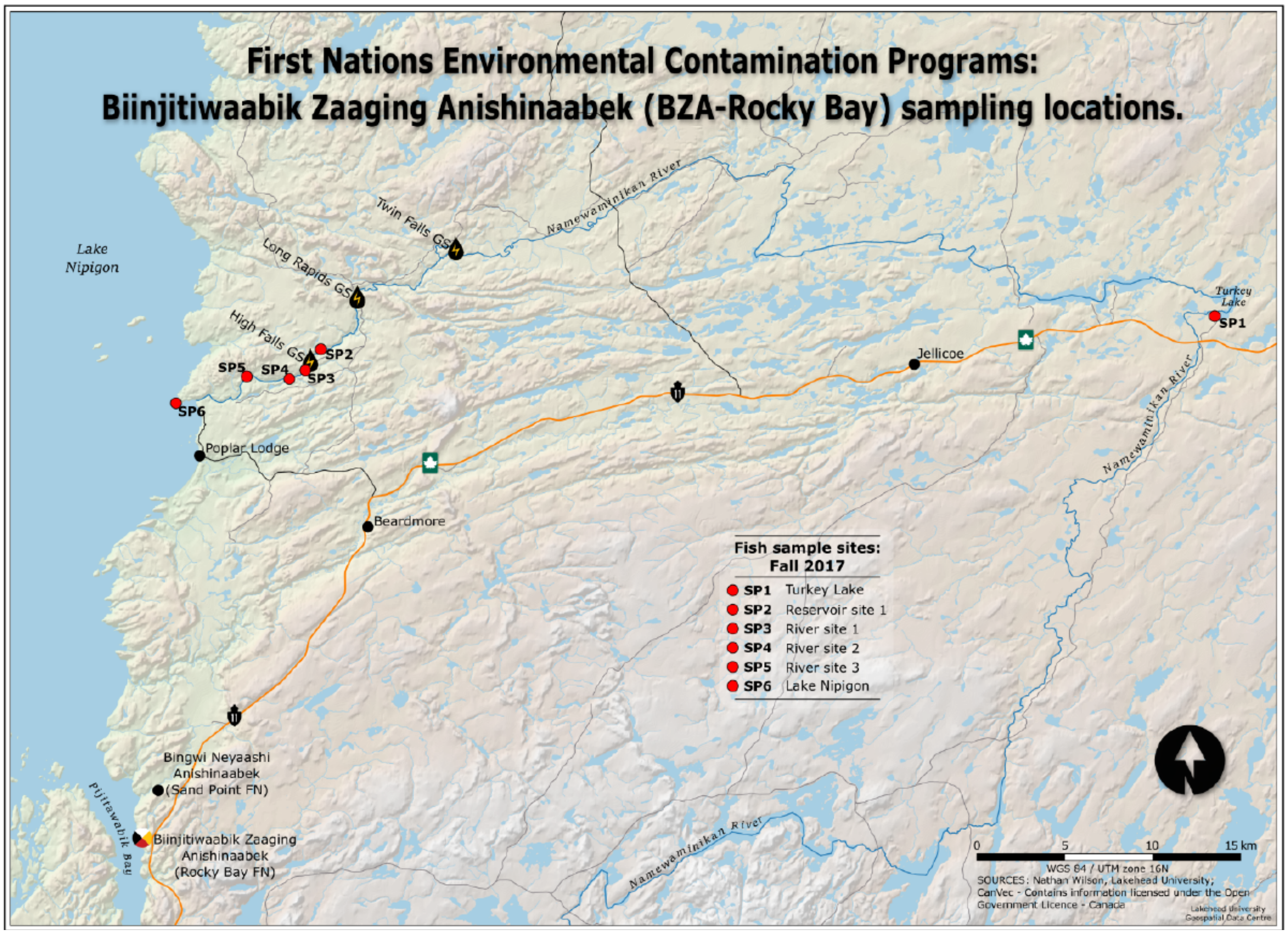

Figure 5.2.1: Namewaminikan River Sample Sites from BZA's 2017 fish contaminant monitoring.

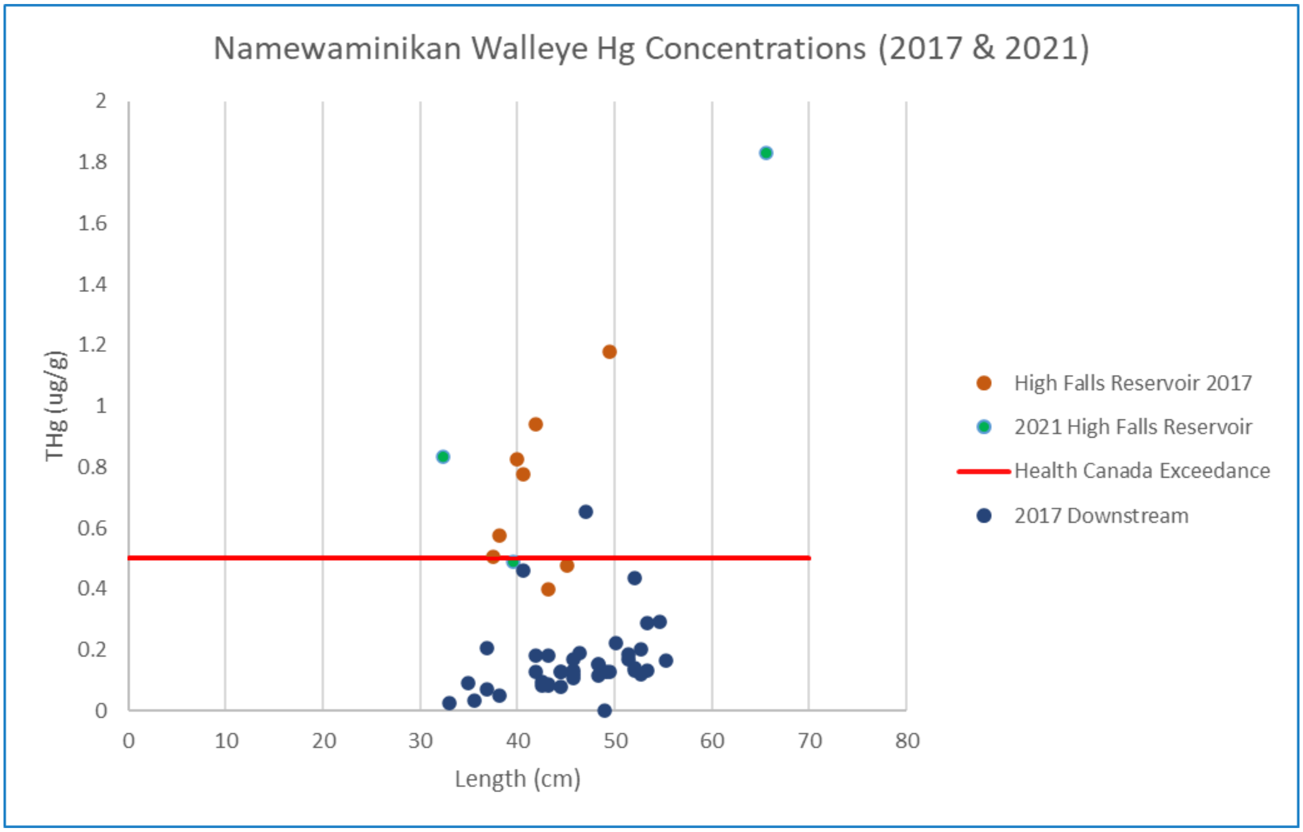

Figure 5.2.2: Walleye total mercury (THg) concentrations and total length from both BZA study periods including samples from within the High Falls reservoir and downstream sample sites (Wilson and Stewart, 2017).

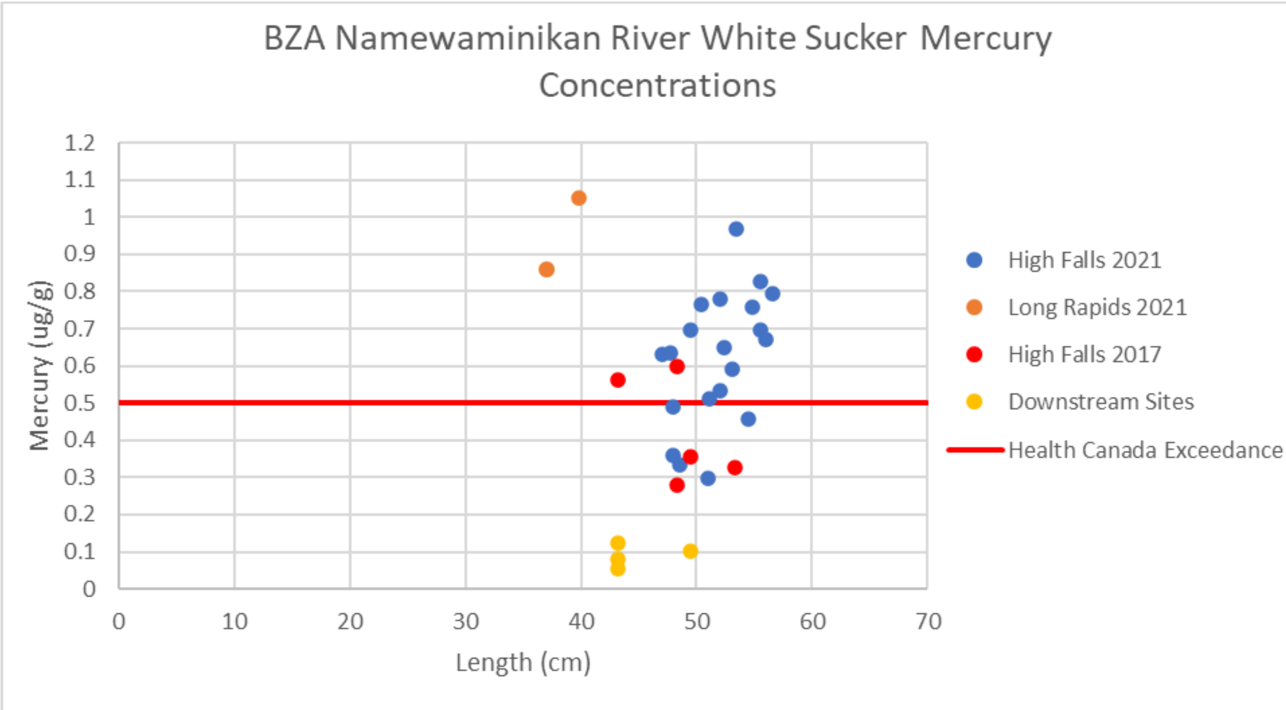

Figure 5.2.3: White Sucker total mercury (THg) concentrations and total length from the High Falls Reservoir and Long Rapids Reservoir collected during both BZA fish contaminant study periods (2017, 2020-2022).

Table 5.2.1: Fish consumption guidelines for White Sucker posted by the OMECP for Namewaminikan River in the High Falls Reservoir and the Blackwater River and those produced by BZA in 2021.

BZA Namewaminikan River (High Falls Reservoir) White Sucker				OMECP Namewaminikan (High Falls Reservoir) River White Sucker (n=24)			OMECP Blackwater River White Sucker		
Length (cm)	Hg (ug/g)	General	Sensitive	Length (cm)	General	Sensitive	Length (cm)	General	Sensitive
30-35	NA	NA	NA	30-35	16	8	35-40	16	8
35-40	NA	NA	NA	35-40	16	4	40-45	16	8
40-45	NA	NA	NA	40-45	12	4	45-50	12	4
45-50	0.59	8	0	45-50	8	4	50-55	8	0
50-55	0.69	4	0	50-55	4	0	55-60	4	0
55-60	0.79	4	0	55-60	4	0	60-65	4	0
NA	NA	NA	NA	60-65	2	0	NA	NA	NA

5.3 Ombabika and Jackfish Rivers

The Ombabika River was used as a reference river since its watershed has had minimal impact from development when compared to the Namewaminikan and Jackfish Rivers. In total 28 and 30 Walleye were collected from the Ombabika and Jackfish rivers respectively by way of angling. Fish from each river exhibited similar Hg concentrations as length increased (Figure 5.3.1), with Jackfish River Walleye having a mean Hg of 2.41ug/g and a mean length of 42.64cm and Ombabika River Walleye a mean Hg of 0.219ug/g and a mean length of 41.0cm, though fish from the Little Jackfish River produced slightly more restrictive consumption guidelines than the Ombabika River. Two fish from the Ombabika River exceeded Health Canada's recommended consumption limit for fish of 0.5ug/g.

In both cases consumption guidelines produced by BZA were less restrictive than those posted for each river by the OMECP (Tables 5.3.1 and 5.3.2). Though two fish from the Ombabika River exceeded Health Canada's recommended consumption limit for fish of 0.5ug/g.

Using the benchmark of approximately 12 meals per month as being considered restrictive for consuming fish in BZA, community-based guidelines recommend that fish greater than 35cm may be restrictive for the sensitive population while no fish within 55cm would be restrictive for the general population in the Little Jackfish River or Ombabika Rivers.

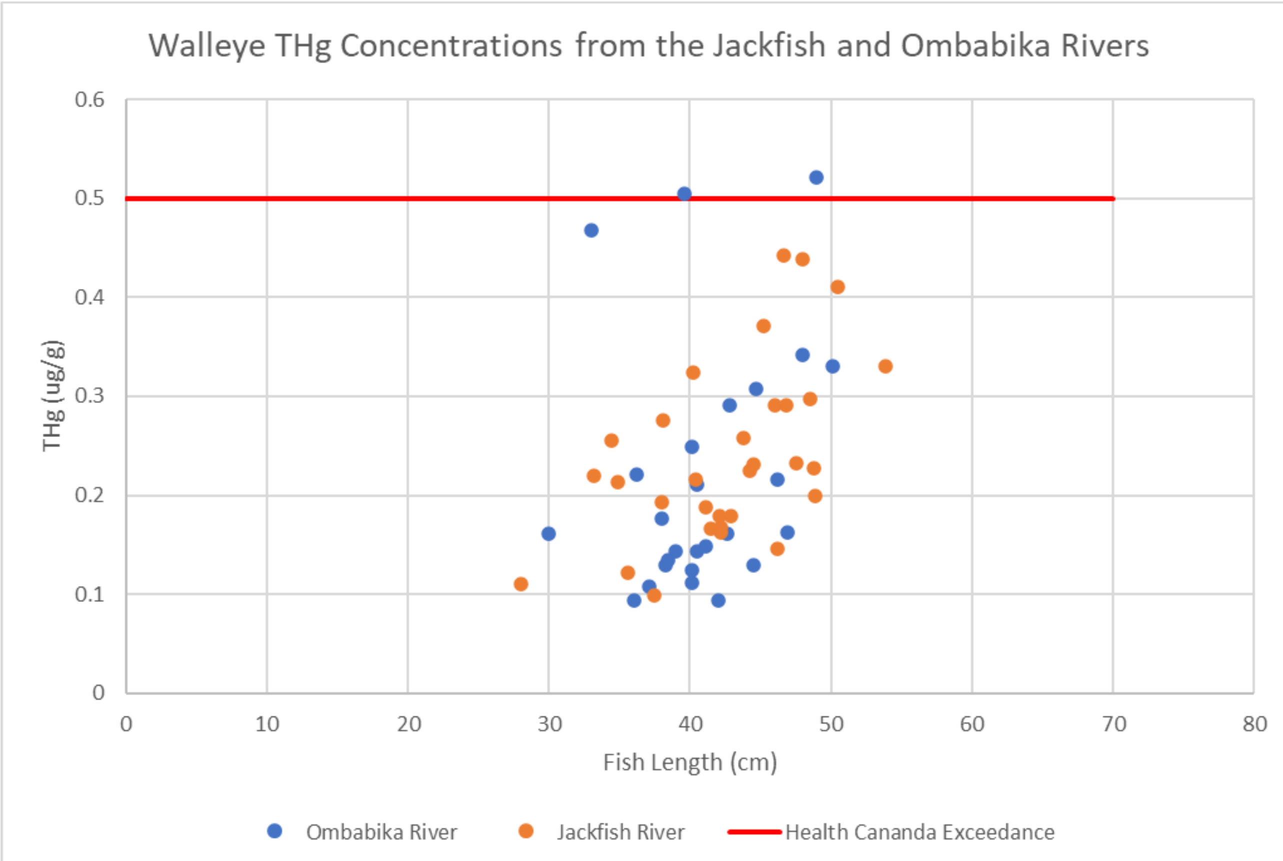

Figure 5.3.1: Fish total mercury (THg) Concentrations for both the Ombabika and Jackfish Rivers. While the Jackfish River produced slightly more restrictive fish consumption guidelines, the Ombabika River had three fish that had the highest THg concentrations between the two rivers, though the Jackfish River

Table 5.3.1: Fish consumption Guidelines for Walleye in the Ombabika River posted by the OMECP and those produced by BZA.

OMECP Ombabika River			**BZA Ombabika River (n=28)**			
Length (cm)	**General**	**Sensitive***	**Length (cm)**	**Hg avg (ug/g)**	**General**	**Sensitive***
30-35	**NA**	**NA**	**30-35**	**0.16**	**16**	**12**
35-40	**NA**	**NA**	**35-40**	**0.19**	**16**	**8**
40-45	**16**	**8**	**40-45**	**0.21**	**16**	**8**
45-50	**12**	**4**	**45-50**	**0.24**	**16**	**8**
50-55	**NA**	**NA**	**50-55**	**0.27**	**16**	**4**

Table 5.3.2: Little Jackfish River fish consumption guidelines for Walleye produced by the Ontario Ministry of Environment Conservation and Parks (OMECP) and BZA.

OMECP Little Jackfish River			BZA Little Jackfish River (n= 30)			
Length (cm)	General	Sensitive*	Length (cm)	Hg (ug/g)	General	Sensitive*
NA	NA	NA	25-30	0.14	32	12
30-35	12	4	30-35	0.17	16	8
35-40	12	4	35-40	0.21	16	8
40-45	8	4	40-45	0.25	16	8
45-50	8	4	45-50	0.29	16	4
50-55	8	4	50-55	0.33	12	4

5.4 Lake Nipigon Consumption Guidelines

Fish consumption Guidelines were produced for four lake locations that BZA identified as important to traditional harvesting of Walleye. Wabinosh Bay had the most restrictive consumption guidelines and highest avg Hg per 5cm bin, followed by McIntyre Bay and Ombabika Bay while Humboldt Bay had the lowest Hg levels (Figure 5.4.1 and Figure 5.4.2) and least restrictive consumption guidelines (Figure 5.3.4). Similar to the river sample sites, these locations had less restrictive fish consumption guidelines when compared to the posted OMECP Lake Nipigon fish consumption guidelines except for the sensitive population at larger size classes in Wabinosh and McIntyre Bay where guidelines were similar and were the same for the general population in McIntyre Bay from 60-65cm and more restrictive for the general population in Wabinosh Bay at 60-65cm. Furthermore, BZA lake sites had lower Hg levels in fish and were less restrictive compared to all river sites as can be seen in Figures 5.1.1 and 5.1.2.

Based on derived BZA fish consumption guidelines, eating fish from Ombabika, Humboldt and McIntyre Bay was not restrictive to the CanNorth consumption average of 12 meals per month for BZA members for the general population. However, fish greater than 60cm in Humboldt Bay (Table 5.4.1) and 45cm in Ombabika (Table 5.4.2) and McIntyre (Table 5.4.3) Bays produced a consumption limit of 8 meals per month which would pose a threat to human health based on the 12 fish meals per month in BZA. In Wabinosh Bay it was found that fish greater than 60cm would be restrictive for the general population and fish greater than 40cm would exceed the Hg levels for 12 meals per month in the sensitive population (Table 5.3.6).

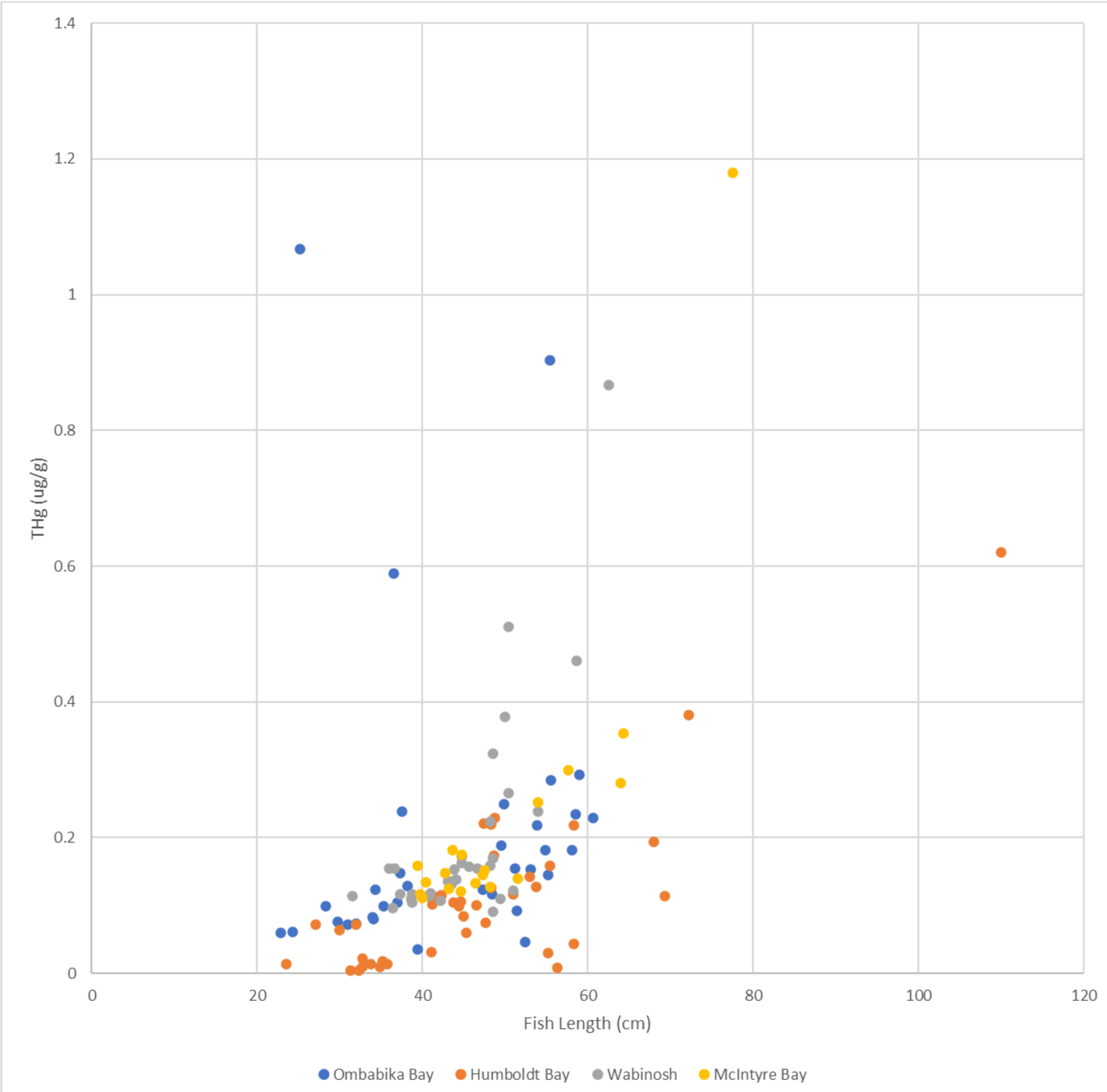

Figure 5.4.1: Fish total mercury (THg) and total length concentrations for all fish caught at lake sites.

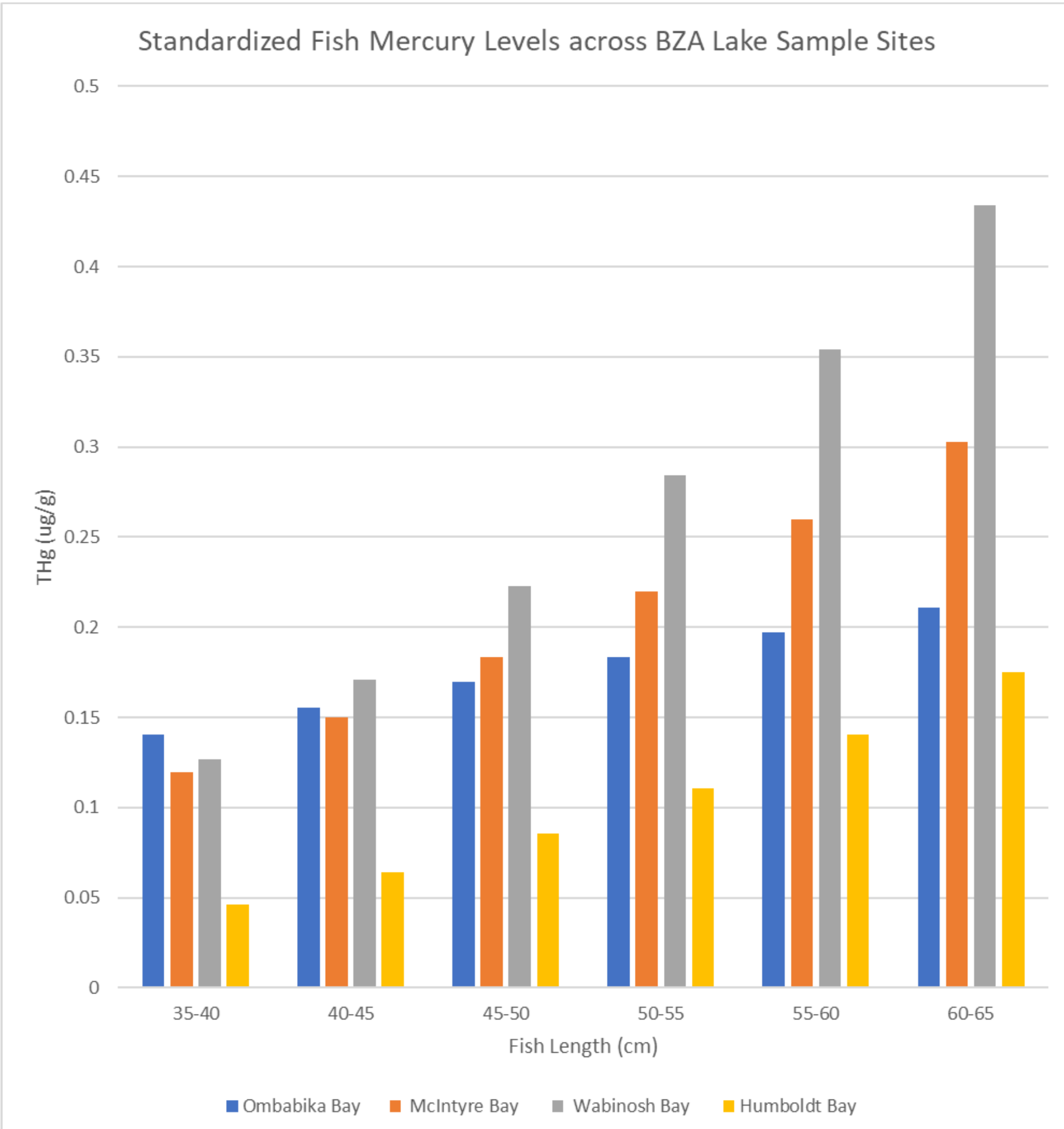

Figure 5.4.2: Estimated total mercury (THg) concentrations for fish with a total length sized 35-65 cm across BZA Lake sampling sites.

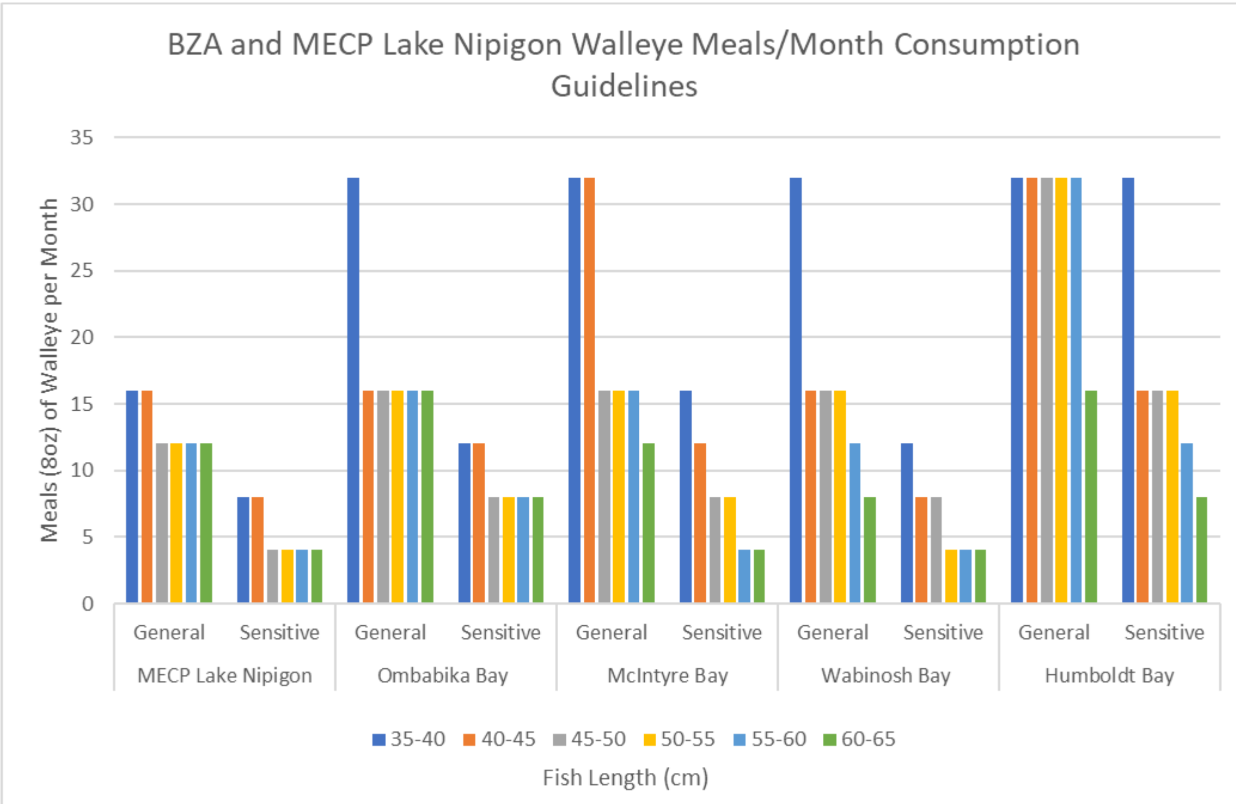

Figure 5.4.3: Fish consumption guidelines produced by BZA compared with the posted Ontario Ministry of Environment Conservation and Parks (OMECP) Lake Nipigon consumption guidelines for Walleye.

Table 5.4.1: Fish consumption guidelines produced by BZA for Walleye caught in Humboldt Bay (n= 40).

Humboldt Bay			
Length (cm)	**Hg avg (ug/g)**	**General Population (meals/month)**	**Sensitive Population (meals/month)**
20-25	**0.013**	**32**	**32**
25-30	**0.021**	**32**	**32**
30-35	**0.032**	**32**	**32**
35-40	**0.046**	**32**	**32**
40-45	**0.064**	**32**	**16**
45-50	**0.085**	**32**	**16**
50-55	**0.111**	**32**	**16**
55-60	**0.140**	**32**	**12**
60-65	**0.175**	**16**	**8**
65-70	**0.214**	**16**	**8**
70-75	**0.259**	**16**	**4**

Table 5.4.2: Fish consumption Guidelines produced by BZA for walleye caught in Ombabika Bay (n= 34).

BZA Ombabika Bay			
Length (cm)	**Hg avg (ug/g)**	**General Population (meals/month)**	**Sensitive Population (meals/month)**
15-20	**0.079**	**32**	**16**
20-25	**0.095**	**32**	**16**
25-30	**0.111**	**32**	**16**
30-35	**0.126**	**32**	**12**
35-40	**0.141**	**32**	**12**
40-45	**0.155**	**16**	**12**
45-50	**0.169**	**16**	**8**
50-55	**0.183**	**16**	**8**
55-60	**0.197**	**16**	**8**
60-65	**0.211**	**16**	**8**

Table 5.4.3: Fish consumption guidelines produced by BZA for Walleye caught in McIntyre Bay. (n=19)

BZA McIntyre Bay			
Length (cm)	**Hg (ug/g)**	**General Population (meals/month)**	**Sensitive Population (meals/month)**
35-40	**0.120**	**32**	**16**
40-45	**0.150**	**32**	**12**
45-50	**0.183**	**16**	**8**
50-55	**0.220**	**16**	**8**
55-60	**0.260**	**16**	**4**
60-65	**0.303**	**12**	**4**

Table 5.4.4: Fish consumption guidelines produced by BZA for Walleye in Wabinosh Bay. (n= 34)

BZA Wabinosh Bay			
Length (cm)	**Hg avg (ug/g)**	**General Population (meals/month)**	**Sensitive Population (meals/month)**
25-30	**0.061**	**32**	**16**
30-35	**0.090**	**32**	**16**
35-40	**0.126**	**32**	**16**
40-45	**0.171**	**16**	**12**
45-50	**0.223**	**16**	**8**
50-55	**0.284**	**16**	**8**
55-60	**0.354**	**12**	**4**
60-65	**0.434**	**8**	**4**

Table 5.4.5: Posted OMECP Walleye consumption guidelines for Lake Nipigon.

OMECP Lake Nipigon		
Length (cm)	**General population (meals/month)**	**Sensitive population (meals/month)**
15-20	**32**	**32**
20-25	**32**	**32**
25-30	**32**	**32**
30-35	**16**	**16**
35-40	**16**	**8**
40-45	**16**	**8**
45-50	**12**	**4**
50-55	**12**	**4**
55-60	**12**	**4**
60-65	**12**	**4**
65-70	**12**	**4**
70-75	**8**	**4**

Chapter 6: Discussion

In this chapter the findings of this study are examined and explained through the following themes: The impacts of hydroelectric development on the Namewaminikan river; The difference in mercury levels in fish and their associated consumption guidelines between river and lake sites; The differences in BZA's consumption results and the posted OMECP guidelines and the benefits of community driven fish consumption guidelines.

6.1 Namewaminikan River

Despite a substantial effort to net fish in three reservoirs of the Namewaminikan River, very few Walleye were actually caught during the study period. Commercial fishermen were shocked to see such low returns with the amount of effort put forward, having set nets on two separate occasions, once in November of 2020 and again in August of 2021. Each time nets were set for approximately 24 hours with very little returns. These results are especially striking when compared to catches in other river systems such as the Ombabika and Little Jackfish. While different methods were used due to the nature of the river systems, the extremely low catch per unit effort in the Namewaminikan River are possibly be related to the extensive hydroelectric development in the river system and represent a concern for the community. Efforts for sampling the river prior to dam constructing and immediately after yielded higher number of Walleye caught between structures, while more monitoring is necessary to confirm this, our results suggest that Walleye numbers in the system are decreasing.

In 2017, there was evidence to suggest that Hg concentrations in White Suckers were higher within the High Falls reservoir when compared to downstream sample sites (Wilson & Stewart, 2017). Once again, fish caught in the High Falls reservoir had higher levels of Hg compared to downstream fish from 2017 and appear to have higher concentrations than those caught in the same location from 2017. More data is needed to produce proper statistical analysis between these sample locations.

With both Walleye and White Suckers exhibiting higher levels of Hg within the High Falls reservoir, there is evidence that this impound is affecting fish mercury levels. Fish Hg levels are expected to return to baseline conditions approximately 30 years after development (Mailman, 2006). The High Falls dam was constructed in 1995, meaning it has been almost 30 years since impoundment and fish Hg levels are still noticeably higher compared to downstream reference sites. With two upstream dams, and literature that has identified the downstream export of Hg from run-of-river and impoundment dams (Bodaly 2011; Schetagne et al., 2000, Silverthorn et al., 2017) it's possible that these newer structures (est. 2017) at Twin Falls and Long Rapids are contributing to the continued elevated levels of mercury in fish tissue within the High Falls reservoir. Run of river dams have been found to act as traps for organic matter and sediments especially in disturbed systems similar to the Namewaminikan River. Elevated Hg and MeHg in the surface sediments in head ponds also correlates with organic matter proportions in sediments (Ferriz et al., 2021). The processing of carbon in headponds and associated increases in MeHg was also observed in a study by Ponton et al., (2020) where Hg and carbon cycles were measured in food webs on a river impacted by multiple run-of-river dams.

Walleye and White Sucker occupy very different trophic levels within aquatic ecosystems, with Walleye being a piscivorous fish and White Suckers typically being benthivores. Walleye may represent a longer time frame of Hg accumulation and can be indicators of ecosystem contaminants, whereas White Suckers feed on benthic invertebrates which may be more indicative of current day contaminant levels in the reservoir because invertebrates take up Hg from the sediment interface (Bauman et al., 1996). With such a large proportion of White Suckers exceeding the Health Canada guidelines, they could be representative of Hg being exported downstream from flooded soil by the Twin Falls and Long Rapids dams. Schetagne et al. 2000, found that dissolved fraction and particulate matter were the main vectors for MeHg transport downstream rather than debris, benthic invertebrates, phytoplankton, or zooplankton. For the Namewaminikan River this could mean that the High Falls reservoir (lowest of the three dams) could be trapping organic particulate matter that is biomagnifying through lower trophic levels (in White Sucker) and into high trophic levels (i.e. Walleye), though with White Sucker Hg levels exceeding those found in Walleye, further investigation is necessary within this reservoir and river system.

6.2 Little Jackfish and Ombabika Rivers

Mercury levels in Walleye sampled in the Little Jackfish River appear to be lower than those found in previous monitoring studies conducted by the OMNRF/MECP as evidenced by the less restrictive consumption guidelines produced from BZA's sampling. However, the Little Jackfish River's fish consumption guidelines are still slightly more restrictive than the neighbouring Ombabika river that is free of major development or cumulative impacts. While the Ombabika River did demonstrate the highest Hg levels between the two rivers, it appears that fish caught within the Little Jackfish River have a slightly higher baseline Hg level on average. It should be noted though, that these differences are minimal as seen in the similar plots of data in Figure 5.2.1.

With a new run-of-river structure being proposed on the Little Jackfish River (Ontario Hydro, 2023) communities and resource managers should be mindful of the risk associated with further hydroelectric development on this river system. This river is still unstable 80 years after the Ogoki Diversion, exhibiting bank slides and continued mass wasting events uncharacteristic of a river in this area (Figure 4.1). A new dam risks further inundation of bank vegetation and soils, and in combination with ongoing erosion from high discharge events, can elevate the amount of mercury that is active in the system (Bodaly et al., 1984; Ripley et al., 2018).

Past monitoring by the Rocky Bay Fisheries Unit found that the Little Jackfish River and Ombabika River act as major sources for the Walleye population of Lake Nipigon. The risk of increased mercury levels in these systems in particular could have a negative influence on the broader lake's Walleye population.

Further monitoring by BZA is necessary to corroborate the declining fish mercury levels in the Little Jackfish River. The current OMECP guidelines are based off sampling that took place in 2012 (per comms) and it is possible that the differences in fish mercury levels today is due to the decline of total mercury levels within the river system post diversion. Furthermore, OMECP guidelines typically use a time scale and older data beyond the 2012 sampling, and this could be why there is a difference between provincial and BZA fish consumption guidelines. BZA Fish Consumption Guidelines therefore provide a current snapshot of contaminant levels related to human health that are based from a large representative sample size in areas of interest to community members.

Across the study fish consumption restrictions were more restrictive at river sites and had higher concentrations of Hg compared to lake sampling locations. Wabinosh Bay had the highest levels of fish mercury and the most restrictive guidelines of lake sample locations. Though it should be noted that Wabinosh Bay’s sampling location was directly at the mouth of the Kopka River, meaning it likely exhibits river system influences similar to the Jackfish and Ombabika

Rivers that have large drainage areas or watersheds. The elevated levels of mercury in Walleye at river sites may also be affected by the many landscape influences of river systems and higher amounts of DOC which often predicts the amount of Hg within an aquatic environment (Driscoll et al., 1995; Hsu-Kim et al., 2013). It is often assumed that pelagic fishes tend to have higher Hg levels compared to those that feed in littoral zones because those in pelagic systems consume larger prey and occupy higher trophic levels, allowing for greater biomagnification. In this study it may be possible that the heightened landscape influences in river systems (i.e., wetlands; erosion; reservoirs) may have caused higher levels of Hg as compared to the sites from the bays of the Lake. Lake Nipigon is also considered an oligotrophic lake with low levels of DOC, while the surrounding watersheds are more characteristic of boreal ecosystems which may contain greater amounts of carbon and mercury. Further study into fish trophic levels through stable isotope analysis could reveal the reason for the difference in river and lake mercury levels (Driscoll et al., 1995; Hall et al., 2005).

These findings have significant implications for fish consumption and the highly valued fishery in Ombabika Bay and its rivers. Between 35.1% and 41.6% of community members surveyed in the CanNorth Country Foods Study indicated that they use the bay for fishing (see Figure 3.2), though communities have a pessimistic view regarding the consumption of fish from the Bay and its rivers due to the history of the Ogoki Diversion. It's important that these findings are communicated effectively to the community and to resource users in the field, to allow them to better understand the levels of risk associated with eating Walleye in the Lake's most productive bay.

6.3 Lake Fish Consumption and Hg levels

Most community concerns centered around fish mercury levels in Ombabika Bay due to the legacy of the Ogoki Diversion. However, fish caught in Ombabika Bay exhibited relatively low concentrations of mercury compared to other lake samples. This is important for the community since Ombabika is an extremely popular location for BZA and members of other communities to harvest Walleye (refer to Figure 3.2). These findings highlight the need for improved communication between resource managers and harvesters of traditional foods. While fishermen and community leaders continuously share concerns over the safety of fish from Ombabika Bay, improved communication of current day fish contaminants could restore the community's comfort in consuming fish from the lake's most productive Walleye fishery. It is possible that the lower Hg levels in Ombabika Bay and associated fish consumption guidelines could be indicative of Walleye Hg levels returning to a baseline. While not seen in the initial 2016 country foods study, a fear of consumption could lead to fewer community members harvesting fish from Ombabika Bay, similar to findings from McAuley and Knopper (2011) where members of the Mohawks of Akwesasne ceased to harvest and consume fish from traditional lands due to legacy pollutants and development.

The spatial distribution of consumption guidelines for community members fishing on Lake Nipigon provides a more accurate description of contaminant levels at traditional fishing locations and provides details from which community members can discuss and understand risk management (Gerstenberger & Dellinger, 2002). These guidelines are meant to inspire more trust and communication between resource users and managers, which in this case is the community itself. The less restrictive guidelines produced by BZA sampling efforts also means that community members can have more confidence when eating fish. This outcome will promote the use of fish consumption guidelines in the community and support the creation of tools such as charts and measuring tapes to use in the field. In this way community members will be better equipped to use the guides to eating fish, rather than just accessing online resources available from the OMECP consumption guidelines for these areas.

Mercury trends in fish across the Great Lakes appear to have been declining over the past half century as atmospheric deposition of Hg has decreased due to limits on emissions (Zhou et al., 2017; Visha et al., 2018). This is especially true for the more northern and oligotrophic lakes of Lake Huron and Lake Superior. Since there is very little historical data and limited literature available for Lake Nipigon, Lake Superior is the closest reference for historical trends of atmospheric deposition. Atmospheric deposition is known to be a major cause of inorganic levels of Hg in aquatic ecosystems (Hall et al. 2005) Recent studies into Lake Superior's spatial and temporal trends of mercury in predatory fish (Walleye & Lake Trout) indicate that the lake's Hg levels have been steadily declining since the 1970s (Zhou et al., 2017; Visha et al., 2018). However, the nearshore environments and littoral fishes associated with bays that are influenced by significant river inputs or disturbed Areas of Concern such as Nipigon Bay, Thunder Bay, and Peninsula Harbour exhibit higher levels of Hg in those top predatory fishes. The results from this study tend to fit those trends, where areas influenced by river inputs have higher Hg levels in fish due to the high amount of wetlands and the dominant substrate of the surrounding watersheds (Hall et al., 2005; Visha et al., 2018).

6.4 Community monitoring and engagement of risks associated with traditional foods

In this study, fish consumption guidelines produced by BZA were generally less restrictive compared to the posted OMECP restrictions. Many factors could contribute to this finding including decreasing temporal trends in Hg concentrations, the effects of sampling procedures on fish size, and trophic level. The results produced by BZA are recent and cover a diverse spatial extent of the Lake and its associated river systems. In all, 212 fish across 7 sample locations were analyzed for mercury and produced fish consumption guidelines for each location. Given the timeline of major hydroelectric development around Lake Nipigon, and the trends in atmospheric deposition of Hg in the Great Lakes, fish Hg levels may have declined over time and is captured in the sample size/locations for this study. Additionally, Lake Nipigon has lost its designated fisheries assessment unit and is now monitored every five years as part of the broadscale monitoring program. BZA's consistent year to year monitoring program of areas of interest provides the most current and robust dataset of fish contaminants in Lake Nipigon. The community's vested interest in the levels of contaminants, traditional knowledge of the ecosystem and inherent risk associated with contaminant exposure means they are essential to the process of assessing and communicating such risks (Brunet et al., 2020; Chan et al., 2021; US EPA, 2023).

Based on the CanNorth country foods survey (2016), having to eat less than 12 meals or 2724g per month of fish would be restrictive to the average BZA community member, then consuming fish greater than 35cm from river locations would be potentially harmful to sensitive populations. In lake settings, fish greater than 40cm in length would restrict the average consumption of fish and have potential harmful effects on people. While these projections assume that all fish consumed are Walleye, they provide an approximate risk assessment of the most severe impacts of fish Hg levels due to the trophic position of Walleye in the ecosystem. Consuming fish in the range of 35-45cm provides sensitive populations with adequate room for error when trying to avoid adverse effects from Hg. This emphasizes the need to communicate the importance of consuming smaller, less mercury laden fish for sensitive and general populations.

In previous studies on Lake Nipigon and elsewhere it has been shown that popular game fish, such as Whitefish, are able to eliminate Hg much faster than Walleye and could be a better alternative to Walleye for those sensitive populations (Gewurtz et al., 2011). These key points for consuming fish should be emphasized when communicating the risk of fish consumption rather than simply posting generalized consumption guidelines for communities. Furthermore, the relatively positive findings of this study show that it’s important to communicate that Walleye in traditional fishing locations are safe to eat, contrary to the belief of many Indigenous peoples around Lake Nipigon.

Chapter 7: Conclusion

This study was successful in combining traditional methods of collecting country foods with western scientific techniques to analyze fish tissue and contaminants in traditional foods (Brunet et al, 2020). The study found that fish consumption guidelines produced by the community were geographically specific, and overall, less restrictive than those posted by the OMECP. Community-based efforts provide for a greater experiential opportunity to learn from and use the data results in community and to apply them within traditional rights and personal risk management opportunities.

The results also show that there is a greater risk of eating fish within river systems compared to lake fishing locations. The study provided valuable spatial reference for mercury in fish across traditionally valued fishing locations and geographies and provides greater detail for risk taking behaviours to occur in the community. The relationship between government and community resource users has created a lack of trust in government data and guidelines (particularly with First Nations). Producing data that the community members can use, trust and hold value in, is critical for the use and understanding of fish consumption guidelines. Community commercial fishermen did not trust government guidelines and regulations since they believed they were "catching different fish". This difference in perspective has led to years of tension between community knowledge holders and government officials. However, when the community is included in practices that are commonly employed by government scientists and western science methodologies, fishermen are interested in the results and the implications of the findings.

For Indigenous communities, the benefits and drawbacks of consuming fish must be weighed independently when concerns regarding contamination of fish exist. This is especially true with regards to the harvesting and consumption of fish in Indigenous communities where these practices have benefits to the cultural, economic, and physical well-being of community members. Indigenous communities are also disproportionately at risk of being exposed to contaminated lands and waters from resource development and extraction (Chan et al., 2021) This is true in the case of Lake Nipigon, where no settler communities are situated directly on the shores of the lake. Furthermore, the reliance on consuming country foods is much less in settler communities due to fewer concerns around food security and traditional practices (US EPA, 2023). This means that Indigenous communities bear the more risk when fish populations are threatened by increased levels of mercury in the environment. Both to their health and Indigenous rights. These communities should be at the forefront of monitoring, research and managing the risk associated with consuming fish.

BZA's studies over the past six years have greatly enhanced the community's knowledge and connection to the current state of fish populations in Lake Nipigon and their associated contaminant levels. The community has continued to build on the fish contaminants monitoring to explore deeper questions of lake health associated with historical and contemporary development and other culturally important species like sturgeon. Though the community has long observed changes and inferred impacts to the lake, they've largely been left out of lake management decisions. This is evident in the collapse of the Walleye fishery in the mid-1990s shortly after the Rock Bay Fisheries Unit had warned that populations were threatened, and a moratorium was needed. The provincial government at the time not only ignored these warnings but also permitted the capture of over 5,000 adult individuals to be relocated for the recovery of the decimated Nipigon Bay Walleye population (Nipigon Bay Remedial Action Plans, 1995). Shortly thereafter, the Ombabika Bay Walleye population collapsed and the commercial quotas for Walleye on Lake Nipigon ceased to exist. This left the traditional fishing community of BZA without its most lucrative economic export. Now that BZA has begun to monitor fish contaminants which directly affect community health, the community can speak from their own dataset and needs when concerns related to contaminants and new developments arise.

As BZA and other communities around Lake Nipigon are consulted with further mining and hydroelectric interests, it's important that they have the capacity to investigate, understand and communicate the potential risks they face from development projects and the exposure to new environmental contaminants. Resource managers should support those who bear the most risk and who should have an integral role in managing those risks. Otherwise, First Nations will continue to be governed by stop gap solutions of paternal management strategies such as traditionally derived fish consumption guidelines, restrictions or advisories.

Having conducted a large-scale fish contaminants study, the community has also increased capacity across its Lands and Resources department. This study has given way to new programs such as the Environmental Guardian Program in BZA where community concerns for any environmental issue are explored with youth and elders in the community. Working with traditional knowledge holders and employing western science techniques, community concerns can be explored in new ways that provide a basis for lake management.

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Appendix

Raw Fish Data

McIntyre Bay Walleye 2021

Fish ID	Mercury (ng/g)	Aluminum (ug/g)	Arsenic (ug/g)	Cadmium (ug/g)	Chromium (ug/g)	Copper (ug/g)	Iron (ug/g)	Manganese (ug/g)	Sulfur (ug/g)	Selenium (ug/g)	Zinc (ug/g)	Sample #	Species	Fork Length (mm)	Length (mm)	Weight (g)	Age
1	139	< 1.01	< 0.65	< 0.070	< 0.070	0.11	1.62	0.157	2194.9	< 0.80	5.35	MB	334	412	515	1150	9
9	134	< 1.01	< 0.65	< 0.070	< 0.070	0.187	2.19	0.097	2214.2	< 0.80	3.71	MB	334	384	404	9g	5
2	133	< 1.01	< 0.65	< 0.070	< 0.070	0.15	2.03	0.211	2107.9	< 0.80	5.76	MB	334	440	464	800	6
3	117	< 1.01	< 0.65	< 0.070	< 0.070	0.222	2.1	0.17	2298.6	< 0.80	6.6	MB	334	378	397	525	5
4	182	< 1.01	< 0.65	< 0.070	< 0.070	0.209	2.69	0.111	2208.1	< 0.80	8.06	MB	334	441	436	525	7
8	148	< 1.01	< 0.65	< 0.070	< 0.070	0.459	4.44	0.118	2226.6	< 0.80	5.67	MB	334	409	428	625	5
5	353	< 1.01	< 0.65	< 0.070	< 0.070	0.106	2.48	0.073	2212.5	< 0.80	3.43	MB	334	610	643	2250	11
10	152	< 1.01	< 0.65	< 0.070	< 0.070	0.148	3.08	0.089	2218.3	< 0.80	4.56	MB	334	446	475	950	6
6	125	1.15	< 0.65	< 0.070	< 0.070	0.122	2.3	0.116	1934	< 0.80	3.78	MB	334	410	432	550	6

7	111	< 1.01	< 0.65	< 0.070	< 0.070	0.114	1.52	0.074	2237.6	< 0.80	4.77	MB	334	378	400	475	5
16	299	< 1.01	< 0.65	< 0.070	< 0.070	0.154	2.56	0.074	2251.2	< 0.80	4.58	MB	334	553	577		11
15	280	< 1.01	< 0.65	< 0.070	< 0.070	0.134	3.15	0.075	2394.9	< 0.80	4.52	MB	334	612	640	9050	10
17	252	< 1.01	< 0.65	< 0.070	< 0.070	0.107	2.84	0.104	2100.5	< 0.80	4.09	MB	334	501	540	1300	10
93	145	< 1.01	< 0.65	< 0.070	< 0.070	0.096	3.27	0.117	2386.5	< 0.80	3.36	MB	334	447	473	725	6
84	127	< 1.01	< 0.65	< 0.070	< 0.070	0.161	2.76	0.087	2086.6	< 0.80	4.29	MB	334	456	482	850	5
94	120	< 1.01	< 0.65	< 0.070	0.073	0.14	2.5	0.097	2132.7	< 0.80	4.29	MB	334	421	446	650	6
95	158	2.37	< 0.65	< 0.070	< 0.070	0.098	3.73	0.165	2261.2	< 0.80	3.28	MB	334	375	394	450	5
96	175	2.91	< 0.65	< 0.070	< 0.070	0.183	5.75	0.121	2119.1	< 0.80	3.46	MB	334	425	448	650	5
11	1180	< 1.01	< 0.65	< 0.070	< 0.070	0.221	6.98	0.072	2080.4	< 0.80	4.04	MB	334	744	775	3400	16

Wabinosh Bay Walleye 2021

Fish ID	Mercury (ng/g)	Aluminum (ug/g)	Arsenic (ug/g)	Cadmium (ug/g)	Chromium (ug/g)	Copper (u/g)	Iron (ug/g)	Manganese (ug/g)	Lead (ug/g)	Nickel (ug/g)	Sulfur (ug/g)	Selenium (ug/g)	Zinc (ug/g)	Species	Fork Length (mm)	Length (mm)	Weight (g)	Age
71	510	< 1.01	< 0.65	< 0.070	< 0.070	0.136	1.76	0.066	< 0.84	< 0.84	2177.3	< 0.80	4.76	334	475	504	1100	14
54	162	< 1.01	< 0.65	< 0.070	< 0.070	0.118	1.59	0.095	< 0.84	< 0.84	2239.5	< 0.80	4.43	334	424	447	800	6
52	136	< 1.01	< 0.65	< 0.070	< 0.070	0.123	1.44	0.099	< 0.84	< 0.84	2216.1	< 0.80	3.77	334	419	436		8
78	114	< 1.01	< 0.65	< 0.070	< 0.070	0.115	1.37	0.087	< 0.84	< 0.84	2228.2	< 0.80	5.06	334	386	409	500	3
60	172	< 1.01	< 0.65	< 0.070	< 0.070	0.148	1.39	0.116	< 0.84	< 0.84	2118	< 0.80	3.96	334	416	447	525	6
70	265	< 1.01	< 0.65	< 0.070	< 0.070	0.155	1.98	0.088	< 0.84	< 0.84	2097.1	< 0.80	4.26	334	427	504	1100	7
82	460	< 1.01	< 0.65	< 0.070	< 0.070	0.114	1.3	0.081	< 0.84	< 0.84	2118.7	< 0.80	5.29	334	556	587	1600	10
55	867	< 1.01	< 0.65	< 0.070	< 0.070	0.118	1.56	0.081	< 0.84	< 0.84	2313.1	< 0.80	5.17	334	595	625	2250	17
57	114	< 1.01	< 0.65	< 0.070	< 0.070	0.1	1.63	0.078	< 0.84	< 0.84	2218	< 0.80	3.88	334	298	315	175	3
74	169	< 1.01	< 0.65	< 0.070	< 0.070	0.145	2.42	0.087	< 0.84	< 0.84	2233.3	< 0.80	5.18	334	458	485	900	7
74	91.2	< 1.01	< 0.65	< 0.070	< 0.070	0.105	1.39	0.103	< 0.84	< 0.84	2219.8	< 0.80	3.31	334	458	485	900	7

59	122	< 1.01	< 0.65	< 0.070	< 0.070	0.191	2.43	0.122	< 0.84	< 0.84	1922.6	< 0.80	3.18	334	459	510	1375	9
69	224	< 1.01	< 0.65	< 0.070	< 0.070	0.096	1.75	0.063	< 0.84	< 0.84	2061.1	< 0.80	3.97	334	451	482	850	7
50	138	< 1.01	< 0.65	< 0.070	< 0.070	0.146	30.08	0.247	< 0.84	< 0.84	2179.1	< 0.80	3.99	334	417	441	975?	5
49	114	< 1.01	< 0.65	< 0.070	< 0.070	0.082	1.32	0.095	< 0.84	< 0.84	2274.3	< 0.80	3.94	334	385	408	500	5
61	135	< 1.01	< 0.65	< 0.070	< 0.070	0.174	3.55	0.091	< 0.84	< 0.84	1992.2	< 0.80	5.17	334	405	431	625	5
81	378	< 1.01	< 0.65	< 0.070	< 0.070	0.142	4.06	0.076	< 0.84	< 0.84	2192.4	< 0.80	5.36	334	472	500	950	8
80	117	< 1.01	< 0.65	< 0.070	< 0.070	0.099	1.67	0.142	< 0.84	< 0.84	2240.8	< 0.80	4.72	334	360	387	450	3
80	104	< 1.01	< 0.65	< 0.070	< 0.070	0.095	1.4	0.095	< 0.84	< 0.84	2155.6	< 0.80	3.28	334	360	387	450	3
51	154	< 1.01	< 0.65	< 0.070	< 0.070	0.088	1.09	0.13	< 0.84	< 0.84	2138.8	< 0.80	5.04	334	439	467	900	5
53	155	< 1.01	< 0.65	< 0.070	< 0.070	0.11	1.4	0.076	< 0.84	< 0.84	2109.8	< 0.80	4.89	334	344	366	400	4
53	155	< 1.01	< 0.65	< 0.070	< 0.070	0.11	1.4	0.076	< 0.84	< 0.84	2109.8	< 0.80	4.89	334	333	360	275	4
58	96.8	< 1.01	< 0.65	< 0.070	< 0.070	0.095	1.36	0.093	< 0.84	< 0.84	2031.1	< 0.80	3.9	334	343	364	350	4
62	159	< 1.01	< 0.65	< 0.070	< 0.070	0.162	2.23	0.053	< 0.84	< 0.84	2314.7	< 0.80	4.09	334	485	482	1100	5

63	238	< 1.01	< 0.65	< 0.070	< 0.070	0.153	1.65	0.072	< 0.84	< 0.84	2180.1	< 0.80	5.31	334	504	540	1200	8
64	153	< 1.01	< 0.65	< 0.070	< 0.070	0.119	1.32	0.098	< 0.84	< 0.84	1988.9	< 0.80	4.15	334	419	439	675	4
75	118	< 1.01	< 0.65	< 0.070	< 0.070	0.088	1.79	0.126	< 0.84	< 0.84	2286.7	< 0.80	3.54	334	388	410	550	4
65	110	< 1.01	< 0.65	< 0.070	< 0.070	0.097	1.73	0.087	< 0.84	< 0.84	2199.2	< 0.80	3.76	334	364	386	450	4
66	107	< 1.01	< 0.65	< 0.070	< 0.070	0.193	2.57	0.1	< 0.84	< 0.84	2194.9	< 0.80	4.22	334	400	422	600	4
67	131	< 1.01	< 0.65	< 0.070	< 0.070	0.102	1.16	0.065	< 0.84	< 0.84	2150	< 0.80	3.12	334	414	435	700	4
68	324	< 1.01	< 0.65	< 0.070	< 0.070	0.474	2	0.097	< 0.84	< 0.84	2136.8	< 0.80	3.98	334	455	485	925	8
77	157	< 1.01	< 0.65	< 0.070	< 0.070	0.097	1.59	0.092	< 0.84	< 0.84	2062.5	< 0.80	3.8	334	434	457	850	5
72	117	< 1.01	< 0.65	< 0.070	< 0.070	0.116	1.59	0.111	< 0.84	< 0.84	2169.5	< 0.80	3.29	334	350	373	350	4
76	110	< 1.01	< 0.65	< 0.070	< 0.070	0.079	2	0.112	< 0.84	< 0.84	2145.8	< 0.80	4.19	334	371	494		5

Ombabika Bay Walleye 2020

Fish ID	FLEN (mm)	TLEN (mm)	RWT (g)	SEX	AGE	Mercury (ng/g)	Aluminum (ug/g)	Arsenic (ug/g)	Cadmium (ug/g)	Chromium (ug/g)	Copper (ug/g)	Iron (ug/g)	Manganese (ug/g)	Nickel (ug/g)	Sulfur (ug/g)	Selenium (ug/g)	Zinc (ug/g)
7	317	340	330	2	4	82.4	< 1.01	< 0.65	< 0.070	< 0.070	0.287	14.83	0.116	< 0.84	1681.3	< 0.80	2.04
8	345	370	375	1	4	105	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.91	0.066	< 0.84	1641.5	< 0.80	1.73
13	285	310	270	2	3	71.6	2.28	0.87	< 0.070	< 0.070	0.118	1.41	0.056	< 0.84	1702.6	< 0.80	2.13
14	484	512	1000	2	9	155	< 1.01	< 0.65	< 0.070	< 0.070	0.083	1.31	0.028	< 0.84	1583.2	< 0.80	1.72
15	570	607	2300	2	9	229	< 1.01	< 0.65	< 0.070	< 0.070	0.129	1.48	0.039	< 0.84	1775.7	< 0.80	2.85
16	466	495	1360	2	10	189	< 1.01	< 0.65	< 0.070	< 0.070	0.128	1.28	0.057	< 0.84	1724.7	< 0.80	2.21
18	508	539	1380	2	11	218.5	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.29	0.05	< 0.84	1871.5	< 0.80	2.52
19	482	581	1620	2	10	181	< 1.01	< 0.65	< 0.070	< 0.070	0.116	1.68	0.04	< 0.84	1591.5	< 0.80	4.16
22	480	514	1220	1	8	92.9	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.13	0.038	< 0.84	1565.8	< 0.80	2.09
23	490	524	1240	2	10	46.1	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.68	0.088	< 0.84	1213.7	< 0.80	2.52
24	350	375	420	1	4	238	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.49	0.06	< 0.84	1482.8	< 0.80	2.27

25	527	554	1400	1	13	903	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.53	0.035	< 0.84	1564.8	< 0.80	2.11
26	359	382	420	1	4	129	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.26	0.044	< 0.84	1588.3	< 0.80	1.64
27	336	353	340	1	4	99.1	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	2.1	0.066	< 0.84	1577.6	< 0.80	2.06
28	227	243	120	9	2	61.3	< 1.01	0.73	< 0.070	< 0.070	< 0.070	1.37	0.066	< 0.84	1598.5	< 0.80	1.91
29	565	590	1740	2	12	292	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.26	0.036	< 0.84	1880.5	< 0.80	2.28
30	520	552	1600	2	8	145	< 1.01	< 0.65	< 0.070	< 0.070	0.283	1.32	0.037	< 0.84	1761.9	< 0.80	2.78
31	497	531	1600	1	8	153	< 1.01	0.69	< 0.070	< 0.070	< 0.070	2.22	0.048	< 0.84	1732.1	< 0.80	2.49
38	434	484	1900	2	5	116	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.35	0.064	< 0.84	1616.3	< 0.80	2.19
39	515	549	1980	2	8	181	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.16	0.043	< 0.84	1889.2	< 0.80	2.51
40	449	473	1060	1	6	124	< 1.01	< 0.65	< 0.070	< 0.070	0.077	1.59	0.067	< 0.84	1860.5	< 0.80	1.85
57	525	555	1900	9	9	284	< 1.01	< 0.65	< 0.070	< 0.070	0.115	3.46	0.051	< 0.84	1310.5	< 0.80	2.82
62	347	373	450	1	5	148	< 1.01	< 0.65	< 0.070	< 0.070	0.071	1.04	0.049	< 0.84	1643.1	< 0.80	2.37
65	258	283	220	9	3	99.4	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.14	0.048	< 0.84	1770.1	< 0.80	2.06

72	319	341	350	1	3	79.4	< 1.01	< 0.65	< 0.070	< 0.070	0.077	1.31	0.087	< 0.84	1731.4	< 0.80	2.59
83	210	229	65	1	5	59.5	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.2	0.758	< 0.84	1443.6	< 0.80	3.71
132	234	252	130			1067	< 1.01	< 0.65	< 0.070	< 0.070	0.126	2.03	0.034	< 0.84	1593.6	< 0.80	2.08
133	279	298	205	9	3	76.6	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.47	0.083	< 0.84	1701.3	< 0.80	2.05
135	301	320	280		3	72.7	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.92	0.096	< 0.84	1453.7	< 0.80	1.99
141	320	343	330	2	4	124	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.56	0.143	< 0.84	1890.8	< 0.80	1.93
151	337	365	800	2	6	588.5	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	0.95	0.034	< 0.84	1903.1	< 0.80	1.53
158	473	499	1120	2	10	249	< 1.01	< 0.65	< 0.070	0.098	< 0.070	2.02	0.058	< 0.84	1899	< 0.80	1.55
172	554	585	2100	2	10	234	< 1.01	< 0.65	< 0.070	< 0.070	0.072	1.25	0.043	< 0.84	1893.7	< 0.80	3.1
176	370	394	460	1	4	35.3	< 1.01	< 0.65	< 0.070	< 0.070	0.076	2.15	0.112	< 0.84	1138.4	< 0.80	1.69

Humboldt Bay 2020 Walleye

Fish ID	FLEN (mm)	TLEN (mm)	RWT (g)	AGE	Mercury (ng/g)	Aluminum (ug/g)	Arsenic (ug/g)	Cadmium (ug/g)	Chromium (ug/g)	Copper (ug/g)	Iron (ug/g)	Manganese (ug/g)	Nickel (ug/g)	Sulfur (ug/g)	Selenium (ug/g)	Zinc (ug/g)
197	636	680	1800	3	194	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.17	0.045	< 0.84	1121.8	< 0.80	1.88
198	435	474	1780	4	221	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.09	0.236	< 0.84	1242.7	< 0.80	2.57
199	685	722	2300	6	381	< 1.01	< 0.65	< 0.070	< 0.070	0.092	1.23	0.042	< 0.84	1195	< 0.80	2.6
200	985	1100	6600	6	620	< 1.01	< 0.65	< 0.070	< 0.070	0.098	1.49	0.056	< 0.84	1497.5	< 0.80	2.58
201	456	486	1180	8	173	2.21	< 0.65	< 0.070	< 0.070	0.153	2.27	0.044	< 0.84	1577.4	< 0.80	2.7
202	420	444	840	4	99.3	1.19	< 0.65	< 0.070	< 0.070	0.147	2.17	0.062	< 0.84	1521.6	< 0.80	2.91
203	520	554	1900	9	159	< 1.01	< 0.65	< 0.070	< 0.070	0.112	1.95	0.056	< 0.84	1460.5	< 0.80	2.27
204	480	510	1260	5	117	< 1.01	< 0.65	< 0.070	< 0.070	0.126	1.53	0.049	< 0.84	1517.7	< 0.80	2.55
205	416	437	960	5	104	3.01	< 0.65	< 0.070	< 0.070	0.077	1.54	0.068	< 0.84	1568.6	< 0.80	3.94
206	437	465	1040	5	101	2	< 0.65	< 0.070	< 0.070	0.071	1.44	0.051	< 0.84	1411.7	< 0.80	2.91
207	449	476	1060	4	74.2	5.39	< 0.65	< 0.070	< 0.070	0.074	1.7	0.06	< 0.84	1420.2	< 0.80	2.18

208	455	483	1120	6	126	1.46	< 0.65	< 0.070	< 0.070	0.084	1.69	0.046	< 0.84	1396.9	< 0.80	2.31
210	399	423	820	4	115	1.62	< 0.65	< 0.070	< 0.070	< 0.070	1.24	0.059	< 0.84	1477.7	< 0.80	1.89
211	392	418	680	5	112	2.03	< 0.65	< 0.070	< 0.070	0.118	1.39	0.058	< 0.84	1447.8	< 0.80	2.31
212	502	530	1560	6	142	1.64	< 0.65	< 0.070	< 0.070	0.075	1.87	0.075	< 0.84	1489.6	< 0.80	2.74
213	431	453	980	4	59.1	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.89	0.05	< 0.84	1265.2	< 0.80	1.84
214	419	446	941	5	106	< 1.01	< 0.65	< 0.070	< 0.070	0.086	1.26	0.032	< 0.84	1446.5	< 0.80	2.29
216	430	450	880	4	84.1	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.29	0.054	< 0.84	1500.3	< 0.80	2.21
217	458	488	1280	8	229	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.75	0.033	< 0.84	1436.3	< 0.80	1.92
218	386	412	800	4	102	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.21	0.046	< 0.84	1462.5	< 0.80	2.25
219	459	483	1080	8	219	< 1.01	< 0.65	< 0.070	< 0.070	0.084	1.81	0.044	< 0.84	1474.3	< 0.80	2.19
262	387	411	700	4	31.9	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.6	0.05	< 0.84	1582.9	< 0.80	2.91
285	332	352	440	3	17.1	< 1.01	< 0.65	< 0.070	< 0.070	0.087	0.96	0.058	< 0.84	1514.5	< 0.80	1.83

286	218	235	120	1	13.3	1.44	< 0.65	< 0.070	< 0.070	0.071	1.42	0.067	< 0.84	1440.2	< 0.80	1.77
290	656	693	1900	5	114	< 1.01	< 0.65	< 0.070	< 0.070	0.114	2.9	0.072	< 0.84	1150.9	< 0.80	3.17
313	551	583	2280	8	43.2	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.71	0.048	< 0.84	1486.7	< 0.80	1.95
314	326	349	420	3	9.63	2.09	< 0.65	< 0.070	< 0.070	0.112	1.54	0.07	< 0.84	1507.5	< 0.80	2.35
315	316	337	360	3	13.1	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.12	0.056	< 0.84	1467.3	< 0.80	1.68
316	336	358	475	3	13.2	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.29	0.064	< 0.84	1601	< 0.80	2.21
317	307	328	335	3	9.33	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.37	0.08	< 0.84	1594.4	< 0.80	2.26
319	520	552	2020	9	30.2	< 1.01	< 0.65	< 0.070	< 0.070	0.094	1.35	0.042	< 0.84	1571	< 0.80	2.58
324	303	327	350	4	22.3	< 1.01	< 0.65	< 0.070	0.218	0.121	2.37	0.068	< 0.84	1536.1	< 0.80	2.28
329	305	323	310	3	3.85	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.47	0.07	< 0.84	1513.1	< 0.80	1.74
331	298	313	260	3	4.25	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	0.91	0.063	< 0.84	1435.8	< 0.80	1.8
336	510	538	1640	6	128	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.42	0.052	< 0.84	1566.9	< 0.80	1.89

337	551	583	2120	9	218	< 1.01	< 0.65	< 0.070	< 0.070	0.186	1.65	0.05	< 0.84	1321.3	< 0.80	2.48
338	284	300	255	2	63.3	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.01	0.062	< 0.84	1583.3	< 0.80	1.92
339	256	271	180	1	71.7	< 1.01	< 0.65	< 0.070	< 0.070	0.304	2.53	0.078	< 0.84	1176.1	< 0.80	1.57
323	527	563	1860	6	7.82	3.29	< 0.65	< 0.070	< 0.070	< 0.070	1.2	0.071	< 0.84	1420.5	< 0.80	1.88
339	300	320	250	2	71.7	< 1.01	< 0.65	< 0.070	< 0.070	0.304	2.53	0.078	< 0.84	1176.1	< 0.80	1.57

Namewaminikan Fish 2021

Sample ID	Fork Length (mm)	Length (mm)	Weight (g)	Species	Location	Mercury (ng/g)	Arsenic (ug/g)	Cadmium (ug/g)	Chromium (ug/g)	Copper (ug/g)	Iron (ug/g)	Manganese (ug/g)	Nickel (ug/g)	Lead (ug/g)	Sulfur (ug/g)	Selenium (ug/g)	Zinc (ug/g)
1	555	510	1900	WS	HF	697	< 0.65	< 0.070	< 0.070	0.221	2.95	0.481	< 0.84	< 0.84	1648.9	< 0.80	2.95
2	655	620	2900	W	HF	1830	< 0.65	< 0.070	< 0.070	0.082	1.66	0.045	< 0.84	< 0.84	2263.3	< 0.80	2.62
3	480	440	2400	WS	HF	358	< 0.65	< 0.070	< 0.070	0.158	3.29	0.262	< 0.84	< 0.84	1576.5	< 0.80	2.36
4	486	450	1800	WS	HF	333	< 0.65	< 0.070	< 0.070	0.213	3.88	0.112	< 0.84	< 0.84	1822.9	< 0.80	3.51
5	560	510	3000	WS	HF	672	< 0.65	< 0.070	0.261	0.261	8.62	0.191	< 0.84	< 0.84	1554	< 0.80	3.5
6	555	520	3200	WS	HF	828	< 0.65	< 0.070	< 0.070	0.193	4.66	0.215	< 0.84	< 0.84	1687.6	< 0.80	3.18
7	545	508	3000	WS	HF	457	< 0.65	< 0.070	< 0.070	0.191	4.16	0.095	< 0.84	< 0.84	1626.9	< 0.80	3.51
8	504	466	1700	WS	HF	765	< 0.65	< 0.070	< 0.070	0.215	4.84	0.1	< 0.84	< 0.84	1693.3	< 0.80	2.35
9	534	495	2600	WS	HF	968	< 0.65	< 0.070	< 0.070	0.185	5.24	0.167	< 0.84	< 0.84	1824.1	< 0.80	2.85
10	520	475	1500	WS	HF	780	< 0.65	< 0.070	< 0.070	0.184	5.1	0.12	< 0.84	< 0.84	1599.9	< 0.80	2.38
11	480	455	1700	WS	HF	491	< 0.65	< 0.070	< 0.070	0.139	2.96	0.229	< 0.84	< 0.84	1544.5	< 0.80	2.32

12	520	476	1200	WS	HF	533	< 0.65	< 0.070	< 0.070	0.13	3.42	0.321	< 0.84	< 0.84	1488.1	< 0.80	2.76
13	510	473	3100	WS	HF	296	< 0.65	< 0.070	< 0.070	0.112	2.92	0.537	< 0.84	< 0.84	1586.7	< 0.80	2.67
14	566	532	3400	WS	HF	796	< 0.65	< 0.070	< 0.070	0.192	5.66	0.405	< 0.84	< 0.84	1622.8	< 0.80	2.77
15	470	434	1800	WS	HF	631	< 0.65	< 0.070	< 0.070	0.159	3.33	0.188	< 0.84	< 0.84	1464.1	< 0.80	2.46
16	511	474	1900	WS	HF	511	< 0.65	< 0.070	< 0.070	0.15	4.31	0.102	< 0.84	< 0.84	1444.8	< 0.80	2.23
17	477	434	1600	WS	HF	633	< 0.65	< 0.070	< 0.070	0.237	8.16	0.652	< 0.84	< 0.84	1579.1	< 0.80	2.83
18	531	480	3000	WS	HF	592	< 0.65	< 0.070	0.37	0.153	4.78	0.129	< 0.84	1.36	1543.4	< 0.80	2.52
19	549	500	3100	WS	HF	759	< 0.65	< 0.070	< 0.070	0.172	6.75	0.166	< 0.84	< 0.84	1670.3	< 0.80	2.68
20	495	439	1900	WS	HF	697	< 0.65	< 0.070	< 0.070	0.378	14.97	0.158	< 0.84	< 0.84	1766.5	< 0.80	4.91
21	524	483	2100	WS	HF	649	< 0.65	< 0.070	< 0.070	0.26	8.36	0.478	< 0.84	< 0.84	1497.1	< 0.80	2.9
22	467	438	1500	WS	HF	814	< 0.65	< 0.070	< 0.070	0.192	6.08	0.287	< 0.84	< 0.84	1524.8	< 0.80	2.55
23	480	446	1600	WS	HF	584	< 0.65	< 0.070	< 0.070	0.176	3.09	0.421	< 0.84	< 0.84	1537.3	< 0.80	2.96
24	531	492	1800	WS	HF	919	< 0.65	< 0.070	< 0.070	0.165	3.75	0.185	< 0.84	< 0.84	1514.2	< 0.80	2.35

25	474	431	1800	WS	HF	695	< 0.65	< 0.070	< 0.070	0.152	3.5	0.112	< 0.84	< 0.84	1496.1	< 0.80	2.22
26	395	373	1100	W	HF	487.5	< 0.65	< 0.070	< 0.070	0.117	2.29	0.078	< 0.84	< 0.84	1813	< 0.80	2.86
27	323	300	600	W	HF	835	< 0.65	< 0.070	< 0.070	0.071	14.12	0.167	< 0.84	< 0.84	2111	< 0.80	2.59
28	371	351	800	WS	LR	856	< 0.65	< 0.070	< 0.070	0.167	2.47	0.178	< 0.84	< 0.84	1503.7	< 0.80	2.57
29	398	364	900	WS	LR	1050	< 0.65	< 0.070	< 0.070	0.122	2.58	0.204	< 0.84	< 0.84	1562.6	< 0.80	2.34
30	503	470	2100	WS	TF	348	< 0.65	< 0.070	< 0.070	0.279	3.79	0.119	< 0.84	< 0.84	1761.8	< 0.80	3.35
31	504	460	1700	WF	TF	134	< 0.65	< 0.070	< 0.070	0.187	3.75	0.119	< 0.84	< 0.84	1849.2	< 0.80	2.51
32	535	501	1700	W	TF	782	< 0.65	< 0.070	< 0.070	0.104	2.03	0.1	< 0.84	< 0.84	2165.6	< 0.80	3.71

Little Jackfish River 2021

Fish ID	Species	Location	Length (cm)	Fork length (cm)	Weight (g)	Methyl Mercury ng/g	Mercury (ng/g)	Aluminium ug/g	Arsenic ug/g	Cadmium ug/g	Chromium ug/g	Copper (ug/g)	Iron (ug/g)	Manganese (ug/g)	Sulfur (ug/g)	Selenium (ug/g)	Zinc (ug/g)
28	334	Jackfish River	46.6	44	900	N	442	< 1.01	< 0.65	< 0.070	0.099	0.166	3.02	0.083	1871.4	< 0.80	5.74
29	334	Jackfish River	33.2	30.9	450	N	220	< 1.01	< 0.65	< 0.070	< 0.070	0.077	0.92	0.064	1919	< 0.80	3.85
30	334	Jackfish River	34.9	32.5	340	N	214	< 1.01	< 0.65	< 0.070	< 0.070	0.08	0.61	0.059	1933.5	< 0.80	3.4
31	334	Jackfish River	35.6	33.6	360	N	122	< 1.01	< 0.65	< 0.070	< 0.070	0.11	1.78	0.1	1905.2	< 0.80	3.42
32	334	Jackfish River	44.5	42	840	N	231	< 1.01	< 0.65	< 0.070	< 0.070	0.121	0.86	0.092	1856.2	< 0.80	3.8
33	334	Jackfish River	28	26	150	N	111	< 1.01	< 0.65	< 0.070	< 0.070	0.089	1.33	0.121	2022.8	< 0.80	3.87
34	334	Jackfish River	48.9	45.3	950	N	200	< 1.01	< 0.65	< 0.070	< 0.070	0.084	0.7	0.066	1757.4	< 0.80	3.74
35	334	Jackfish River	46.8	44	850	N	291	< 1.01	< 0.65	< 0.070	< 0.070	0.088	0.98	0.04	1926.1	< 0.80	3.46

36	334	Jackfish River	48.8	46	920	N	228	< 1.01	< 0.65	< 0.070	< 0.070	0.098	0.61	0.054	1915.6	< 0.80	4.03
37	334	Jackfish River	41.5	39.3	610	N	166	< 1.01	< 0.65	< 0.070	< 0.070	0.081	0.94	0.113	2043.6	< 0.80	3.28
38	334	Jackfish River	43.8	41	800	N	258	< 1.01	< 0.65	< 0.070	< 0.070	0.225	0.86	0.06	2182.3	< 0.80	3.75
39	334	Jackfish River	47.5	45	960	N	232	1.01	< 0.65	< 0.070	0.512	0.139	3.88	0.09	2081.9	< 0.80	3.93
40	334	Jackfish River	46	42.9	800	173	291	< 1.01	< 0.65	< 0.070	0.223	0.171	2.82	0.097	2292.4	< 0.80	4.94
41	334	Jackfish River	38.1	36	400	162	275.5	< 1.01	< 0.65	< 0.070	< 0.070	0.1	1.94	0.086	1992.8	< 0.80	2.74
42	334	Jackfish River	50.5	48	1050	379	411	< 1.01	< 0.65	< 0.070	< 0.070	0.2	1.83	0.091	2082.2	< 0.80	4.22
43	334	Jackfish River	48.5	45.5	1170	187	297	< 1.01	< 0.65	< 0.070	< 0.070	0.241	1.92	0.074	2249.4	< 0.80	6.02
44	334	Jackfish River	44.2	41.5	800	124	225	2.92	< 0.65	< 0.070	< 0.070	0.152	3.81	0.082	2153.5	< 0.80	4.05
45	334	Jackfish River	34.4	32	320	164	255	< 1.01	< 0.65	< 0.070	< 0.070	0.136	2.15	0.089	2164	< 0.80	2.82

46	334	Jackfish River	48	45.3	1010	148	439	< 1.01	< 0.65	< 0.070	< 0.070	0.465	1.91	0.088	2181.7	< 0.80	4.29
47	334	Jackfish River	42.1	40.5	670	91	179	< 1.01	< 0.65	< 0.070	< 0.070	0.144	0.89	0.085	2061.2	< 0.80	3.35
48	334	Jackfish River	42.2	39.9	710	83	163	< 1.01	< 0.65	< 0.070	< 0.070	0.184	0.84	0.1	2122.5	< 0.80	3.57
49	334	Jackfish River	42.9	40.5	710	56	179	< 1.01	< 0.65	< 0.070	< 0.070	0.146	3.04	0.101	2174.5	< 0.80	3.29
50	334	Jackfish River	41.1	38.4	600	100	188	< 1.01	< 0.65	< 0.070	< 0.070	0.118	1.23	0.057	2246.2	< 0.80	3.91
51	334	Jackfish River	40.2	38	580	N	324	< 1.01	< 0.65	< 0.070	< 0.070	0.144	3.34	0.079	2068.8	< 0.80	3.88
52	334	Jackfish River	38	35.3	410	N	193	< 1.01	< 0.65	< 0.070	< 0.070	0.102	1.2	0.099	2147.6	< 0.80	4
53	334	Jackfish River	40.4	38.9	550	N	216	< 1.01	< 0.65	< 0.070	< 0.070	0.105	1.05	0.054	1974.2	< 0.80	3.82
54	334	Jackfish River	46.2	43.9	930	N	146	1.15	< 0.65	< 0.070	< 0.070	0.134	6.77	0.121	2125.5	< 0.80	3.55
55	334	Jackfish River	37.5	35	470	N	99	< 1.01	< 0.65	< 0.070	< 0.070	0.101	2.14	0.063	1882.1	< 0.80	4.54

56	334	Jackfish River	53.9	49.5	1420	N	330	< 1.01	< 0.65	< 0.070	< 0.070	0.121	1.41	0.082	2148.9	< 0.80	3.34
57	334	Jackfish River	42.2	39.8	570	N	168	< 1.01	< 0.65	< 0.070	< 0.070	0.112	0.71	0.066	2279.3	< 0.80	2.6
58	334	Jackfish River	45.2	43.2	860	N	371	< 1.01	< 0.65	< 0.070	< 0.070	0.125	0.79	0.061	2179	< 0.80	3

Ombabika River Fish 2022

Fish ID	Species	Location	Length (cm)	Fork length (cm)	Weight (g)	Methyl Mercury ng/g	Mercury ng/g	Aluminium ug/g	Arsenic ug/g	Cadmium ug/g	Chromium ug/g	Copper ug/g	Iron ug/g	Manganese ug/g	Lead ug/g	Nickel ug/g	Sulfur ug/g	Selenium ug/g	Zinc ug/g
1	334	Ombabika River	39	37	0	104	143.5	< 1.01	< 0.65	< 0.070	0.209	0.446	3.71	0.102	< 0.84	< 0.84	1961.8	< 0.80	4.24
2	334	Ombabika River	48	45.5	0	192	342	1.92	< 0.65	< 0.070	< 0.070	0.125	4.07	0.175	< 0.84	< 0.84	1969.4	< 0.80	4.11
3	334	Ombabika River	40.1	37.8	0	61	125	< 1.01	< 0.65	< 0.070	< 0.070	0.071	0.94	0.092	< 0.84	< 0.84	1902.7	< 0.80	3.32
4	334	Ombabika River	40.5	38	0	109	143	< 1.01	< 0.65	< 0.070	< 0.070	0.175	0.98	0.072	< 0.84	< 0.84	1727.7	< 0.80	3.31
5	334	Ombabika River	36.2	34	0	167	221	< 1.01	< 0.65	< 0.070	< 0.070	0.092	1.21	0.076	< 0.84	< 0.84	1873.5	< 0.80	2.35
6	334	Ombabika River	50.1	47.5	0	197	331	< 1.01	< 0.65	< 0.070	< 0.070	0.1	1.16	0.053	< 0.84	< 0.84	1764.4	< 0.80	3.7
7	334	Ombabika River	30	28.1	0	155	161	< 1.01	< 0.65	< 0.070	0.083	0.272	3.7	0.076	< 0.84	< 0.84	1628.7	< 0.80	2.39
8	334	Ombabika River	38	35.7	0	112	176	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	0.88	0.155	< 0.84	< 0.84	1857.3	< 0.80	3.35

9	334	Omba bika River	40.5	38	0	117	211	< 1.01	< 0.65	< 0.070	< 0.070	0.075	1.25	0.071	< 0.84	< 0.84	1860.1	< 0.80	3.48
10	334	Omba bika River	42.6	40.1	0	151	161	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	0.83	0.059	< 0.84	< 0.84	1959.7	< 0.80	3.42
11	334	Omba bika River	49	46	0	N	521	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	0.84	0.056	< 0.84	< 0.84	1954.9	< 0.80	3.04
12	334	Omba bika River	36	34	0	N	93.5	< 1.01	< 0.65	< 0.070	0.076	< 0.070	1.84	0.086	< 0.84	< 0.84	1694.6	< 0.80	3.18
13	334	Omba bika River	42.8	40.4	0	N	291	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	0.96	0.087	< 0.84	< 0.84	1994.5	< 0.80	4.21
14	334	Omba bika River	38.3	36.2	0	N	130	< 1.01	< 0.65	< 0.070	< 0.070	0.109	0.94	0.103	< 0.84	< 0.84	1980.3	< 0.80	4.44
15	334	Omba bika River	37.1	35	0	N	108	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	0.53	0.093	< 0.84	< 0.84	1874.3	< 0.80	3.37
16	334	Omba bika River	42	39.7	0	N	94.2	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	0.86	0.095	< 0.84	< 0.84	1862.9	< 0.80	2.79
17	334	Omba bika River	38.4	36.1	0	N	135	< 1.01	< 0.65	< 0.070	< 0.070	0.079	0.73	0.103	< 0.84	< 0.84	1796.8	< 0.80	2.43
18	334	Omba bika River	39.6	37	0	N	504	3.12	< 0.65	< 0.070	< 0.070	0.07	5.81	0.101	< 0.84	< 0.84	1816.5	< 0.80	2.08

19	334	Omba bika River	41.1	39.2	0	N	148	< 1.01	< 0.65	< 0.070	< 0.070	0.073	0.57	0.089	< 0.84	< 0.84	1903.3	< 0.80	2.52
20	334	Omba bika River	40.1	38.1	0	N	112	< 1.01	< 0.65	< 0.070	< 0.070	0.088	1.11	0.078	< 0.84	< 0.84	1887.4	< 0.80	3.89
21	334	Omba bika River	44.7	42	0	N	308	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.48	0.077	< 0.84	< 0.84	1682.6	< 0.80	3.48
22	334	Omba bika River	46.2	43.3	0	N	216	< 1.01	< 0.65	< 0.070	< 0.070	0.096	1.04	0.074	< 0.84	< 0.84	1865.9	< 0.80	4.07
23	334	Omba bika River	46.9	43.8	0	N	163	< 1.01	< 0.65	< 0.070	< 0.070	0.084	0.43	0.059	< 0.84	< 0.84	1791.5	< 0.80	2.88
24	334	Omba bika River	40.1	37.9	0	N	249	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	1.37	0.062	< 0.84	< 0.84	1765.2	< 0.80	1.98
25	334	Omba bika River	44.5	41.1	0	N	130	< 1.01	< 0.65	< 0.070	< 0.070	< 0.070	0.68	0.086	< 0.84	< 0.84	1932.9	< 0.80	2.67
26	334	Omba bika River	33	31	0	N	468	< 1.01	< 0.65	< 0.070	< 0.070	0.071	1.05	0.058	< 0.84	< 0.84	1730.7	< 0.80	2.77